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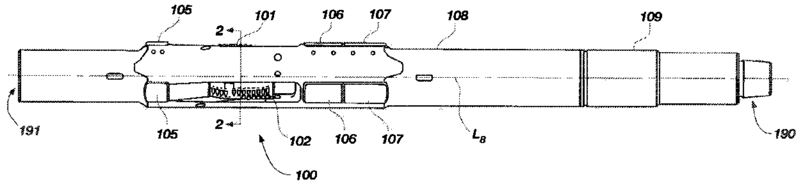

FIG. 1

(57) **Abstract**: An expandable reamer apparatus for drilling a subterranean formation includes a tubular body, one or more blades, each blade positionally coupled to a sloped track of the tubular body having a hardfacing material on a portion thereof, a push sleeve and a drilling fluid flow path extending through an inner bore of the tubular body for conducting drilling fluid therethrough.

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CHIP DEFLECTOR ON A BLADE OF A DOWNHOLE REAMER AND METHODS THEREFOR

PRIORITY CLAIM

This application claims the benefit of the filing date of United States Patent Application Serial Number 61/156,936, filed March 3, 2009, for "CHIP DEFLECTOR ON A BLADE OF A DOWNHOLE REAMER AND METHOD THEREFOR."

TECHNICAL FIELD

The present invention relates generally to improved blades for an expandable reamer apparatus for drilling a subterranean borehole and, more particularly, to improved blades for an expandable reamer apparatus for enlarging a subterranean borehole beneath a casing or liner.

BACKGROUND

Expandable reamers are typically employed for enlarging subterranean boreholes. Conventionally in drilling oil, gas, and geothermal wells, casing is installed and cemented to prevent the well bore walls from caving into the subterranean borehole while providing requisite shoring for subsequent drilling operations to achieve greater depths. Casing is also conventionally installed to isolate different formations, to prevent crossflow of formation fluids, and to enable control of formation fluids and pressure as the borehole is drilled. To increase the depth of a previously drilled borehole, new casing is laid within and extended below the previous casing. While adding additional casing allows a borehole to reach greater depths, it has the disadvantage of narrowing the borehole. Narrowing the borehole restricts the diameter of any subsequent sections of the well because the drill bit and any further casing must pass through the existing casing. As reductions in the borehole diameter are undesirable because they limit the production flow rate of oil and gas through the borehole, it is often desirable to enlarge a subterranean borehole to provide a larger borehole diameter for installing additional casing beyond previously installed casing as well as to enable better production flow rates of hydrocarbons through the borehole.

A variety of approaches have been employed for enlarging a borehole diameter. One conventional approach used to enlarge a subterranean borehole includes using eccentric and bi-center bits. For example, an eccentric bit with a laterally extended or enlarged cutting portion is rotated about its axis to produce an enlarged borehole diameter. An example of an eccentric bit is disclosed in U.S. Pat. No. 4,635,738, assigned to the assignee of the present invention. A bi-center bit assembly employs two longitudinally superimposed bit sections with laterally offset axes, which when rotated produce an enlarged borehole diameter. An example of a bi-center bit is disclosed in U.S. Pat. No. 5,957,223, which is also assigned to the assignee of the present invention.

Another conventional approach used to enlarge a subterranean borehole includes employing an extended bottomhole assembly with a pilot drill bit at the distal end thereof and a reamer assembly some distance above. This arrangement permits the use of any standard rotary drill bit type, be it a rock bit or a drag bit, as the pilot bit, and the extended nature of the assembly permits greater flexibility when passing through tight spots in the borehole as well as the opportunity to effectively stabilize the pilot drill bit so that the pilot hole and the following reamer will traverse the path intended for the borehole. This aspect of an extended bottomhole assembly is particularly significant in directional drilling. The assignee of the present invention has, to this end, designed as reaming structures so called “reamer wings,” which generally comprise a tubular body having a fishing neck with a threaded connection at the top thereof and a tong die surface at the bottom thereof, also with a threaded connection. U.S. Pat. Nos. 5,497,842 and 5,495,899, both assigned to the assignee of the present invention, disclose reaming structures including reamer wings. The upper midportion of the reamer wing tool includes one or more longitudinally extending blades projecting generally radially outwardly from the tubular body, the outer edges of the blades carrying PDC cutting elements.

As mentioned above, conventional expandable reamers may be used to enlarge a subterranean borehole and may include blades pivotably or hingedly affixed to a tubular body and actuated by way of a piston disposed therein as disclosed by U.S. Pat. No. 5,402,856 to Warren. In addition, U.S. Pat. No. 6,360,831 to Åkesson et al. discloses a conventional borehole opener comprising a body equipped with at least two hole opening arms having cutting means that may be moved from a position of rest in the body to an active position by exposure to pressure of the drilling fluid flowing through the body. The blades in these reamers are initially retracted to permit the tool to be run through the borehole on a drill string and once the tool has passed beyond the end of the casing, the blades are extended so the bore diameter may be increased below the casing.

The blades of conventional expandable reamers have been sized to minimize a clearance between themselves and the tubular body in order to prevent any drilling mud and earth fragments from becoming lodged in the clearance and binding the blade against the tubular body. The blades of these conventional expandable reamers utilize pressure from inside the tool to apply force radially outward against pistons which move the blades, carrying cutting elements, laterally outward. It is felt by some that the nature of the conventional reamers allows misaligned forces to cock and jam the pistons and blades, preventing the springs from retracting the blades laterally inward. Also, designs of these conventional expandable reamer assemblies fail to help blade retraction when jammed and pulled upward against the borehole casing. Furthermore, some conventional hydraulically actuated reamers utilize expensive seals disposed around a very complex shaped and expensive piston, or blade, carrying cutting elements. In order to prevent cocking, some conventional reamers are designed having the piston shaped oddly in order to try to avoid the supposed cocking, requiring matching, complex seal configurations. These seals are feared to possibly leak after extended usage.

Hardfacing has been used in the downhole tool art for some time as a way to increase the erosion and abrasion resistance of certain areas of roller cone bits and steel body bits. Relatively thin layers of hardfacing have been applied to relatively large areas where erosion and abrasion from cuttings, high-velocity fluid and contact with the formation causes undesirable wear on the bit. Steel bits, such as roller cone bits, exhibit much more erosive and abrasive wear than so-called matrix bits which are manufactured by infiltration of molten metal into a matrix material comprising tungsten carbide or other powder. Many fixed cutter drill bits are manufactured from tungsten carbide matrix, as well as from steel. Steel body bits tend to exhibit superior toughness but limited erosion and abrasion resistance, whereas matrix bits tend to exhibit reduced toughness but exemplary erosion and abrasion resistance.

Hardfacing is generally composed of some form of hard particles delivered to a surface via a welding delivery system. Hardfacing refers to the deposited material rather than the constituent materials which make up the hardfacing. Constituent materials of hardfacing are referred to as a hardfacing composition. Hard particles may come from the following group of cast or sintered carbides consisting of chromium, molybdenum, niobium, tantalum, titanium, tungsten, and vanadium, and alloys and mixtures thereof, as disclosed by U.S. Patent No. 5,663,512 to Schader et al., assigned to the assignee of the present invention. Commonly, a mixture of sintered, macrocrystalline, or cast tungsten carbides is captured within a mild steel tube. The steel tube containing the carbide mixture is then used as a welding rod to deposit hardfacing onto the desired surface, usually with a deoxidizer, or flux.

The shape, size, and relative percentage of different hard particles will affect the wear and toughness properties of the deposited hardfacing, as described by Schader et al. U.S. Patent No. 5,492,186 to Overstreet, assigned to the assignee of the present invention, describes a hardfacing configuration for heel row teeth on a roller cone drill bit. The coating comprises two hardfacing compositions tailored for different properties. A first hardfacing composition may be characterized by good sliding wear resistance and/or abrasion resistance with a lower level of toughness. The second hardfacing composition contains carbide particles of spherical sintered, crushed sintered and cast tungsten carbide. A substantial portion of the particles in the second composition are characterized by a higher level of fracture resistance, or toughness, and a lower level of abrasion resistance.

Hardfacing compositions have been also used for coating the gage surfaces of roller cone teeth, as disclosed in U.S. Patent No. 3,800,891 to White et al. White also discloses, with respect to the hardfacing of teeth on a milled steel tooth rolling cone-type bit, circumferential grooves and a transverse slot on each roller cone tooth for the deposition of hardfacing.

Hardfacing has been utilized with steel body bits in certain circumstances. For example, U.S. Patent No. 4,499,958 to Radtke et al. discloses hardfacing on the blades and other portions of the bit subject to abrasive wear. However, use of hardfacing material as taught by Radtke et al. does not address issue of material toughness as may be required for various portions of the bit while also exploiting the advantages of an abrasion-resistant material.

So-called matrix bits, aforementioned for their superior abrasion and erosion resistance, have also been contemplated as benefitting from hardfacing as well. U.S. Patent No. 4,884,477 to Smith et al., assigned to the assignee of the present invention, discloses a metal matrix bit body composed of a filler material of higher toughness than tungsten carbide with substantially all of the internal and external surfaces of the bit body coated with an erosion- and abrasion-resistant hardfacing comprised of tungsten carbide or silicon carbide. However, Smith et al. does not address strategic localization of a material according to its characteristics of either abrasion resistance or material toughness. Smith et al. fail to particularly address such issues with regard to a steel body bit.

Chip breakers serve to influence the formation of chips which are initiated at the leading edges of cutters and are pushed along the surface of a blade of the bit carrying the cutters such that they are weakened and subsequently broken into smaller elements during the drilling process. Such a chip breaker is described in greater detail in U.S. Patent No. 5,582,258 to Tibbitts et al., assigned to the assignee of the present invention. Chip breakers form a "bump" in the surface of the blade and in the direct path of the formation of the chip which causes the chip to break before becoming overly elongated. This breakage prevents chips from building up along the surface of the bit and possibly balling the bit with an agglomeration of chips, as is known in the art. Chip breakers in steel body bits may be machined into the surface of the bit; however, this too may place limits on the bit design.

Gage elements for steel body bits are typically formed by drilling holes into the gage surface and pressing sintered tungsten carbide cylinders into the holes. As an additional measure, a layer of hardfacing may be applied around the sintered carbide cylinders, on the body of the bit, but the cylinders function as the main elements to prevent abrasion and wear on the gage, and are designed and configured to maximize the exposed area of the sintered cylinders to the borehole sidewall. Although sintered carbide cylinders function adequately as a drill bit gage, the necessity of milling precise holes for press fitting is cumbersome and limits the configuration of the gage. In addition, sintered carbide gage cylinders often exhibit cracking after use, referred to as crazing, perhaps attributable to the extreme heating and cooling cycles present during drilling conditions.

Notwithstanding the various prior approaches to drill and/or ream a larger diameter borehole below a smaller diameter borehole, the need exists for improved apparatus and methods for doing so. In view of the shortcomings in the art, it would be advantageous to provide an expandable reamer employing structural blades having hardfacing materials on portions thereof.

Accordingly, there is an ongoing desire to improve or extend performance of an expandable reamer apparatus regardless of the subterranean formation type being drilled. There is a further desire to provide a reamer apparatus that provides fail-safe blade retraction, is robustly designed with conventional seal or sleeve configurations, and may not require sensitive tolerances between moving parts.

DISCLOSURE OF THE INVENTION

An expandable reamer apparatus for drilling a subterranean formation including a tubular body, one or more blades positionally coupled to the track of the tubular body, a push sleeve and a drilling fluid flow path extending through the tubular body for conducting drilling fluid therethrough are disclosed. The tubular body includes a longitudinal axis, an inner bore, an outer surface, and at least one track communicating through the tubular body between the inner bore and the outer surface, the track exhibiting a slope at an acute angle to the longitudinal axis. The one or more blades each include hardfacing thereon and least one cutting element configured and oriented to remove material from the wall of a borehole of a subterranean formation to enlarge the borehole diameter responsive to rotation of the apparatus. The push sleeve is positionally coupled to the inner bore of the tubular body and coupled to at least one blade so as to be configured to selectively allow communication of drilling fluid passing through the tubular body to effect axial movement thereof responsive to a force or pressure of drilling fluid so as to transition the at least one blade along the track from a retracted position into an extended position for reaming.

BRIEF DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming that which is regarded as the invention, various features and advantages of this invention may be more readily ascertained from the following description of the invention when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a side view of an embodiment of an expandable reamer apparatus of the invention;

FIG. 2 shows a transverse cross-sectional view of the expandable reamer apparatus as indicated by section line 2-2 in FIG. 1;

FIG. 3 shows a longitudinal cross-sectional view of the expandable reamer apparatus shown in FIG. 1 as indicated by section line 3-3 in FIG. 2;

FIG. 4 shows an enlarged longitudinal cross-sectional view of a portion of the expandable reamer apparatus shown in FIG. 3;

FIG. 5 shows an enlarged cross-sectional view of another portion of the expandable reamer apparatus shown in FIG. 3;

FIG. 6 shows an enlarged cross-sectional view of yet another portion of the expandable reamer apparatus shown in FIG. 3;

FIG. 7 shows an enlarged cross-sectional view of a further portion of the expandable reamer apparatus shown in FIG. 3;

FIG. 8 shows a cross-sectional view of a shear assembly of an embodiment of the expandable reamer apparatus;

FIG. 9 shows a cross-sectional view of a nozzle assembly of an embodiment of the expandable reamer apparatus;

FIG. 10 shows a top view of a blade in accordance with an embodiment of the invention;

FIG. 10A shows a top view of a blade in accordance with an embodiment of the invention using hardfacing;

FIG. 11 shows a longitudinal cross-sectional view of the blade taken along section line 11-11 in FIG. 10;

FIG. 12 shows a longitudinal end view of the blade of FIG. 10;

FIG. 13 shows a cross-sectional view taken along section line 13-13 in FIG. 11;

FIG. 14 shows a cross-sectional view taken along section line 14-14 in FIG. 11;

FIG. 14A shows a cross-sectional view taken along section line 14-14 in FIG. 11 of a blade having hardfacing on a portion thereof;

FIG. 14B shows a cross-sectional view taken along section line 14-14 in FIG. 11 of a blade having hardfacing on a portion thereof;

FIG. 14C shows a cross-sectional view taken along section line 14-14 in FIG. 11 of a blade having hardfacing on a portion thereof;

FIG. 14D shows a cross-sectional view taken along section line 14-14 in FIG. 11 of a blade having hardfacing on a portion thereof;

FIG. 14E shows a cross-sectional view taken along section line 14-14 in FIG. 11 of a blade having prior to having hardfacing thereon;

FIG. 15 shows a cross-sectional view of an uplock sleeve of an embodiment of the expandable reamer apparatus;

FIG. 16 shows a perspective view of a yoke of an embodiment of the expandable reamer apparatus;

FIG. 17 shows a partial, longitudinal cross-sectional illustration of an embodiment of the expandable reamer apparatus in a closed, or retracted, initial tool position;

FIG. 18 shows a partial, longitudinal cross-sectional illustration of the expandable reamer apparatus of FIG. 17 in the initial tool position, receiving a ball in a fluid path;

FIG. 19 shows a partial, longitudinal cross-sectional illustration of the expandable reamer apparatus of FIG. 17 in the initial position tool in which the ball moves into a ball seat and is captured;

FIG. 20 shows a partial, longitudinal cross-sectional illustration of the expandable reamer apparatus of FIG. 17 in which a shear assembly is triggered as pressure is accumulated and a traveling sleeve begins to move down within the apparatus, leaving the initial tool position;

FIG. 21 shows a partial, longitudinal cross-sectional illustration of the expandable reamer apparatus of FIG. 17 in which the traveling sleeve moves toward a lower, retained position while a blade being urged by a push sleeve under the influence of fluid pressure moves toward an extended position;

FIG. 22 shows a partial, longitudinal cross-sectional illustration of the expandable reamer apparatus of FIG. 17 in which the blades (one depicted) are held in the fully extended position by the push sleeve under the influence of fluid pressure and the traveling sleeve moves into the retained position;

FIG. 23 shows a partial, longitudinal cross-sectional illustration of the expandable reamer apparatus of FIG. 17 in which the blades (one depicted) are retracted into a retracted position by a biasing spring when the fluid pressure is dissipated;

FIG. 24 shows a partial, longitudinal cross-sectional view of a expandable reamer apparatus including a borehole dimension measurement device in accordance with another embodiment of the invention;

FIG. 25 shows a longitudinal cross-sectional view of an embodiment of the expandable reamer apparatus incorporating a motion limiting member; and

FIG. 26 shows a longitudinal cross-sectional view of an embodiment of the expandable reamer apparatus incorporating another motion limiting member.

MODE(S) FOR CARRYING OUT THE INVENTION

The illustrations presented herein are, in some instances, not actual views of any particular reamer tool, cutting element, or other feature of a reamer tool, but are merely idealized representations that are employed to describe the present invention. Additionally, elements common between figures may retain the same numerical designation.

An expandable reamer apparatus 100 according to an embodiment of the invention is shown in FIG. 1. The expandable reamer apparatus 100 may include a generally cylindrical tubular body 108 having a longitudinal axis L_8. The tubular body 108 of the expandable reamer apparatus 100 may have a lower end 190 and an upper end 191. The terms "lower" and "upper," as used herein with reference to the ends 190, 191, refer to the typical positions of the ends 190, 191 relative to one another when the expandable reamer apparatus 100 is positioned within a well bore. The lower end 190 of the tubular body 108 of the expandable reamer apparatus 100 may include a set of threads (e.g., a threaded male pin member) for connecting the lower end 190 to another section of a drill string or another component of a bottomhole assembly

(BHA), such as, for example, a drill collar or collars carrying a pilot drill bit for drilling a well bore. Similarly, the upper end 191 of the tubular body 108 of the expandable reamer apparatus 100 may include a set of threads (e.g., a threaded female box member) for connecting the upper end 191 to another section of a drill string or another component of a bottomhole assembly (BHA).

Three sliding cutter blocks or blades 101, 102, 103 (see FIG. 2) are positionally retained in circumferentially spaced relationship in the tubular body 108 as further described below and may be provided at a position along the expandable reamer apparatus 100 intermediate the first lower end 190 and the second upper end 191. The blades 101, 102, 103 may be comprised of steel, tungsten carbide, a particle-matrix composite material (e.g., hard particles dispersed throughout a metal matrix material), or other suitable materials as known in the art. The blades 101, 102, 103 are retained in an initial, retracted position within the tubular body 108 of the expandable reamer apparatus 100 as illustrated in FIG. 17, but may be moved responsive to application of hydraulic pressure into the extended position (shown in FIG. 22) and moved into a retracted position (shown in FIG. 23) when desired, as will be described herein. The expandable reamer apparatus 100 may be configured such that the blades 101, 102, 103 engage the walls of a subterranean formation surrounding a well bore in which the expandable reamer apparatus 100 is disposed to remove formation material when the blades 101, 102, 103 are in the extended position, but are not operable to so engage the walls of a subterranean formation within a well bore when the blades 101, 102, 103 are in the retracted position. While the expandable reamer apparatus 100 includes three blades 101, 102, 103, it is contemplated that one, two or more than three blades may be utilized to advantage. Moreover, while the blades 101, 102, 103 are symmetrically circumferentially positioned axially along the tubular body 108, the blades 101, 102, 103 may also be positioned circumferentially asymmetrically as well as asymmetrically along the longitudinal axis L_8 in the direction of either end 190 and 191.

FIG. 2 is a cross-sectional view of the expandable reamer apparatus 100 shown in FIG. 1 taken along section line 2-2 shown therein. As shown in FIG. 2, the tubular body 108 encloses a fluid passageway 192 that extends longitudinally through the tubular body 108. The fluid passageway 192 directs fluid substantially through an inner bore 151 of a traveling sleeve 128 in bypassing relationship to substantially shield the blades 101, 102, 103 from exposure to drilling fluid, particularly in the lateral direction, or normal to the longitudinal axis L_8. Advantageously, the particulate-entrained fluid is less likely to cause build-up or interfere with the operational aspects of the expandable reamer apparatus 100 by shielding the blades 101, 102, 103 from exposure with the fluid. However, it is recognized that beneficial shielding of the blades 101, 102, 103 is not necessary to the operation of the expandable reamer apparatus 100 where, as explained in further detail below, the operation, i.e., extension from the initial position, the extended position and the retracted position, occurs by an axially directed force that is the net effect of the fluid pressure and spring biasing forces. In this embodiment, the axially directed force directly actuates the blades 101, 102, 103 by axially influencing the actuating means, such as a push sleeve 115 (shown in FIG. 3), for example, and without limitation, as better described herein below.

Referring to FIG. 2, to better describe aspects of the invention, blades 102 and 103 are shown in the initial or retracted positions, while blade 101 is shown in the outward or extended position. The expandable reamer apparatus 100 may be configured such that the outermost radial or lateral extent of each of the blades 101, 102, 103 is recessed within the tubular body 108 when in the initial or retracted positions so it may not extend beyond the greatest extent of the outer diameter of the tubular body 108. Such an arrangement may protect the blades 101, 102, 103 as the expandable reamer apparatus 100 is disposed within a casing of a borehole, and may allow the expandable reamer apparatus 100 to pass through such casing within a borehole. In other embodiments, the outermost radial extent of the blades 101, 102, 103 may coincide with or slightly extend beyond the outer diameter of the tubular body 108. As illustrated by blade 101, the blades may extend beyond the outer diameter of the tubular body 108 when in the extended position, to engage the walls of a borehole in a reaming operation.

FIG. 3 is another cross-sectional view of the expandable reamer apparatus 100 shown in FIGS. 1 and 2 taken along section line 3-3 shown in FIG. 2. Reference may also be made to FIGS. 4-7, which show enlarged partial longitudinal cross-sectional views of various portions of the expandable reamer apparatus 100 shown in FIG. 3. Reference may also be made back to FIGS. 1 and 2 as desired. The tubular body 108 positionally respectively retains three sliding cutter blocks or blades 101, 102, 103 in three blade tracks 148. The blades 101, 102, 103 each carry a plurality of cutting elements 104 for engaging the material of a subterranean formation defining the wall of an open borehole when the blades 101, 102, 103 are in an extended position (shown in FIG. 22). The cutting elements 104 may be polycrystalline diamond compact (PDC) cutters or other cutting elements known to a person of ordinary skill in the art and as generally described in U.S. Pat. No. 7,036,611 entitled "Expandable Reamer Apparatus for Enlarging Boreholes While Drilling and Methods of Use."

The expandable reamer apparatus 100 includes a shear assembly 150 for retaining the expandable reamer apparatus 100 in the initial position by securing the traveling sleeve 128 toward the upper end 191 thereof. Reference may also be made to FIG. 8, showing a partial view of the shear assembly 150. The shear assembly 150 includes an uplock sleeve 124, some number of shear screws 127 and the traveling sleeve 128. The uplock sleeve 124 is retained within an inner bore 151 of the tubular body 108 between a lip 152 and a retaining ring 132 (shown in FIG. 7), and includes an O-ring seal 135 to prevent fluid from flowing between the outer bore 153 of the uplock sleeve 124 and the inner bore 151 of the tubular body 108. The uplock sleeve 124 includes shear slots 154 for retaining each of the shear screws 127, where, in the current embodiment of the invention, each shear screw 127 is threaded into a shear port 155 of the traveling sleeve 128. The shear screws 127 hold the traveling sleeve 128 within the inner bore 156 of the uplock sleeve 124 to conditionally prevent the traveling sleeve 128 from axially moving in a downhole direction 157, i.e., toward the lower end 190 of the expandable reamer apparatus 100. The uplock sleeve 124 includes an inner lip 158 to prevent the traveling sleeve 128 from moving in the uphole direction 159, i.e., toward the upper end 191 of the expandable reamer apparatus 100. An O-ring seal 134 seals the traveling sleeve 128 between the inner bore 156 of the uplock sleeve 124. When the shear screws 127 are sheared, the traveling sleeve 128 is allowed to axially travel within the tubular body 108 in the downhole direction 157. Advantageously, the portions of the shear screws 127 when sheared are retained within the uplock sleeve 124 and the traveling sleeve 128 in order to prevent the portions from becoming loose or being lodged in other components when drilling the borehole. While shear screws 127 are shown, other shear elements may be used to advantage, for example, without limitation, a shear rod, a shear wire and a shear pin. Optionally, other shear elements may include structure for positive retention within constituent components after being exhausted, similar in manner to the shear screws 127 of the current embodiment of the invention.

With reference to FIG. 6, uplock sleeve 124 further includes a collet 160 that axially retains a seal sleeve 126 between the inner bore 151 of the tubular body 108 and an outer bore 162 of the traveling sleeve 128. The uplock sleeve 124 also includes one or more ears 163 and one or more ports 161 axially spaced there around (see FIG. 15). When the traveling sleeve 128 positions a sufficient axial distance in downhole direction 157, the one or more ears 163 spring radially inward to lock the motion of the traveling sleeve 128 between the one or more ears 163 of the uplock sleeve 124 and between a shock absorbing member 125 mounted upon an upper end of the seal sleeve 126. Also, as the traveling sleeve 128 positions a sufficient axial distance in the downhole direction 157, the one or more ports 161 of the uplock sleeve 124 are fluidly exposed, allowing fluid to communicate with a nozzle intake port 164 from the fluid passageway 192 (FIG. 2). The shock absorbing member 125 of the seal sleeve 126 provides spring retention of the traveling sleeve 128 with the one or more ears 163 of the uplock sleeve 124 and also mitigates impact shock caused by the traveling sleeve 128 when its motion is stopped by the seal sleeve 126.

Shock absorbing member 125 may comprise a flexible or compliant material, such as, for instance, an elastomer or other polymer. In one embodiment, shock absorbing member 125 may comprise a nitrile rubber. Utilizing a shock absorbing member 125 between the traveling sleeve 128 and seal sleeve 126 may reduce or prevent deformation of at least one of the traveling sleeve 128 and seal sleeve 126 that may otherwise occur due to impact therebetween.

It should be noted that any sealing elements or shock absorbing members disclosed herein that are included within expandable reamer apparatus 100 may comprise any suitable material as known in the art, such as, for instance, a polymer or elastomer. Optionally, a material comprising a sealing element may be selected for relatively high temperature (e.g., about 400° Fahrenheit or greater) use. For instance, seals may be comprised of TEFLON®, polyetheretherketone ("PEEK™") material, a polymer material, or an elastomer, or may comprise a metal-to-metal seal suitable for expected borehole conditions. Specifically, any sealing element or shock absorbing member disclosed herein, such as shock absorbing member 125 and sealing elements, such as O-ring seals 134 and 135, discussed hereinabove, or sealing elements, such as T-seal seal 137, discussed herein below, or other sealing elements included by an expandable reamer apparatus of the invention may comprise a material configured for relatively high temperature use, as well as for use in highly corrosive borehole environments.

The seal sleeve 126 includes an O-ring seal 136 sealing it between the inner bore 151 of the tubular body 108, and a T-seal seal 137 sealing it between the outer bore 162 of the traveling sleeve 128, which completes fluid sealing between the traveling sleeve 128 and the nozzle intake port 164. Furthermore, the seal sleeve 126 axially aligns, guides and supports the traveling sleeve 128 within the tubular body 108. Moreover, the O-ring seal 136 and T-seal seal 137, respectively, may also prevent hydraulic fluid from leaking from within the expandable reamer apparatus 100 to outside the expandable reamer apparatus 100 by way of the nozzle intake port 164 prior to the traveling sleeve 128 being released from its initial position.

A downhole end 165 of the traveling sleeve 128 (also see FIG. 5), which includes a seat stop sleeve 130, is aligned, axially guided and supported by an annular piston or lowlock sleeve 117. The lowlock sleeve 117 is axially coupled to a push sleeve 115 that is cylindrically retained between the traveling sleeve 128 and the inner bore 151 of the tubular body 108. When the traveling sleeve 128 is in the "ready" or initial position during drilling, the hydraulic pressure may act on the push sleeve 115 concentric to the tool axis and upon the lowlock sleeve 117 between the outer bore 162 of the traveling sleeve 128 and the inner bore 151 of the tubular body 108. With or without hydraulic pressure when the expandable reamer apparatus 100 is in the initial position, the push sleeve 115 is prevented from moving in the uphole direction 159 by a lowlock assembly, i.e., one or more dogs 166 of the lowlock sleeve 117.

The dogs 166 are positionally retained between an annular groove 167 in the inner bore 151 of the tubular body 108 and the seat stop sleeve 130. Each dog 166 of the lowlock sleeve 117 is a collet or locking dog latch having an expandable detent 168 that may engage the annular groove 167 of the tubular body 108 when compressively engaged by the seat stop sleeve 130. The dogs 166 hold the lowlock sleeve 117 in place and prevent the push sleeve 115 from moving in the uphole direction 159 until the "end" or seat stop sleeve 130, with its larger outer diameter 169, travels beyond the lowlock sleeve 117 allowing the dogs 166 to retract axially inward toward the smaller outer diameter 170 of the traveling sleeve 128. When the dogs 166 retract axially inward they may be disengaged from the annular groove 167 of the tubular body 108, allowing the push sleeve 115 to be subjected to hydraulic pressure primarily in the axial direction, i.e., in the uphole direction 159.

The shear assembly 150 requires an affirmative act, such as introducing a ball or other restriction element into the expandable reamer apparatus 100 to cause the pressure from hydraulic fluid flow to increase, before the shear screws 127 will shear.

The downhole end 165 of the traveling sleeve 128 includes within its inner bore a ball trap sleeve 129 that includes a plug 131. An O-ring seal 139 may also provide a seal between the ball trap sleeve 129 and the plug 131. A restriction element in the form of a ball 147 (FIG. 18) may be introduced into the expandable reamer apparatus 100 in order to enable operation of the expandable reamer apparatus 100 to initiate or "trigger" the action of the shear assembly 150. After the ball 147 is introduced, fluid will carry the ball 147 into the ball trap sleeve 129 allowing the ball 147 to be retained and sealed by the seat part of the plug 131 and the ball trap sleeve 129. When the ball 147 occludes fluid flow by being trapped in the ball trap sleeve 129, the fluid or hydraulic pressure will build up within the expandable reamer apparatus 100 until the shear screws 127 shear. After the shear screws 127 shear, the traveling sleeve 128 along with the coaxially retained seat stop sleeve 130 will axially travel, under the influence of the hydraulic pressure, in the downhole direction 157 until the traveling sleeve 128 is again axially retained by the uplock sleeve 124 as described above or moves into a lower position. Thereafter, the fluid flow may be re-established through the fluid ports 173 in the traveling sleeve 128 above the ball 147.

Optionally, the ball 147 used to activate the expandable reamer apparatus 100 may engage the ball trap sleeve 129 and the plug 131 that include malleable characteristics, such that the ball 147 may swage therein as it seats in order to prevent the ball 147 from moving around and potentially causing problems or damage to the expandable reamer apparatus 100.

Also, in order to support the traveling sleeve 128 and mitigate vibration effects after the traveling sleeve 128 is axially retained, the seat stop sleeve 130 and the downhole end 165 of the traveling sleeve 128 are retained in a stabilizer sleeve 122. Reference may also be made to FIGS. 5 and 22. The stabilizer sleeve 122 is coupled to the inner bore 151 of the tubular body 108 and retained between a retaining ring 133 and a protect sleeve 121, which is held by an annular lip 171 in the inner bore 151 of the tubular body 108. The retaining ring 133 is held within an annular groove 172 in the inner bore 151 of the tubular body 108. The protect sleeve 121 provides protection from the erosive nature of the hydraulic fluid to the tubular body 108 by allowing hydraulic fluid to flow through fluid ports 173 of the traveling sleeve 128, impinge upon the protect sleeve 121 and past the stabilizer sleeve 122 when the traveling sleeve 128 is retained therein.

After the traveling sleeve 128 travels sufficiently far enough to allow the dogs 166 of the lowlock sleeve 117 to be disengaged from the annular groove 167 of the tubular body 108, the dogs 166 of the lowlock sleeve 117, being connected to the push sleeve 115, may all move in the uphole direction 159. Reference may also be made to FIGS. 5, 6 and 21. In order for the push sleeve 115 to move in the uphole direction 159, the differential pressure between the inner bore 151 and an outer side 183 (FIG. 9) of the tubular body 108 caused by the hydraulic fluid flow must be sufficient to overcome the restoring force or bias of a spring 116 (FIG. 3). The compression spring 116 that resists the motion of the push sleeve 115 in the uphole direction 159, is retained on an outer surface 175 of the push sleeve 115 between a ring 113 attached in a groove 174 of the tubular body 108 and the lowlock sleeve 117. The push sleeve 115 may axially travel in the uphole direction 159 under the influence of the hydraulic fluid, but is restrained from moving beyond the top lip of the ring 113 and beyond a protect sleeve 121 in the downhole direction 157. The push sleeve 115 may include a T-seal seal 138 between the tubular body 108, a T-seal seal 137 between the traveling sleeve 128, and a wiper seal 141 between the traveling sleeve 128 and push sleeve 115.

The push sleeve 115 includes at its uphole section 176, a yoke 114 coupled thereto as shown in FIG. 6. The yoke 114 (also shown in FIG. 16) includes three arms 177, each arm 177 being coupled to one of the blades 101, 102, 103 by a pinned linkage 178. The arms 177 may include a shaped surface suitable for expelling debris as the blades 101, 102, 103 are retracted toward the retracted position. The shaped surface of the arms 177, in conjunction with the adjacent wall of the cavity of the tubular body 108, may provide included angles of approximately 20 degrees, which is preferable to dislodge and remove any packed-in shale, and may further include low friction surface material to prevent sticking by formation cuttings and other debris. The pinned linkage 178 includes a linkage 118 coupling a blade to the arm 177, where the linkage 118 is coupled to the blade by a blade pin 119 and secured by a retaining ring 142, and the linkage 118 is coupled to the arm 177 by a yoke pin 120 which is secured by a cotter pin 144. The pinned linkage 178 allows the blades 101, 102, 103 to rotationally transition about the arms 177 of the yoke 114, particularly as the actuating means directly transitions the blades 101, 102, 103 between the extended and retracted positions. Advantageously, the actuating means, i.e., the push sleeve 115, the yoke 114, and or the pinked linkage 178, directly retracts as well as extends the blades 101, 102, 103, whereas conventional wisdom has directed the use of one part for harnessing hydraulic pressure to force the blades laterally outward and another part, such as a spring, to force the blades inward.

In order that the blades 101, 102, 103 may transition between the extended and retracted positions, they are each positionally coupled to one of the blade tracks 148 in the tubular body 108 as particularly shown in FIGS. 3 and 6. The blade 101 is also shown in FIGS. 10-14E.

As previously stated, the blades 101, 102, 103 may be comprised of steel, tungsten carbide, a particle-matrix composite material (e.g., hard particles dispersed throughout a metal matrix material), or other suitable materials as known in the art. A blade 101, 102, 103 comprises a blade body including a plurality of primary cutter pockets 185 and secondary cutter pockets 186 located behind the primary cutter pockets 185, although the secondary cutter pockets 186 may be located within the kerf of a primary cutter pocket 185 but displaced from the centerline thereof. Additionally, although blades 101, 102, 103 have a primary cutter pockets 185 and secondary cutter pockets 186 therein, additional cutter pockets and cutting elements may be used on the blades as well as wear knots, and the like. Each of the primary cutter pockets 185 and secondary cutter pockets 186 have a cutting element 104 located therein. Each blade 101, 102, 103 includes a gage portion 101′ (see FIG. 10), typically having a primary cutter pocket 185 having a cutting element 104 therein, although such may not be included in the gage portion 101′ if such is desired. To decrease or reduce wear from chips and debris from the borehole on the tubular body 108, the front surface 201 of each blade 101, 102, 103 may include a chip breaker thereon (see FIGS. 14A-14D). Illustrated in FIG. 14A is a cross-section of a blade 101, 102, 103 having a chip breaker 203 located on surface 205 of the blade 101, 102, 103 to use where a chip is traveling along surface 205 of the blade 101, 102, 103 until the chip contacts the chip breaker 203 when the chip is deflected and/or broken. The chip breaker 203 comprises suitable well-known hardfacing material applied to the surface 205 of the blade 101, 102, 103 using well known manual or computer controlled techniques for the application of hardfacing to well tools. The hardfacing material may be machined, ground, or otherwise shaped into any desired geometric shape for use as a chip breaker 203. A preferred hardfacing material is described in U.S. Patent No. 5,663,512, which has been reissued as U.S. Patent Re. 37,127, entitled "HARDFACING COMPOSITION FOR EARTH BORING BITS." As illustrated, the chip breaker 203 has been shaped to have a concave curved surface 203′ thereon to deflect chips contacting such a surface. Illustrated in FIG. 14B is a chip breaker 207 located on surface 205 of a blade 101, 102, 103 comprised of suitable hardfacing which has been machined, ground, or otherwise shaped into a substantially square geometric shape 207′ having substantially flat sides to deflect chips contacting such chip breaker 207. Illustrated in FIG. 14C is a chip breaker 209 located on surface 205 of blade 101, 102, 103 comprised of suitable hardfacing material which has been machined, ground, or otherwise shaped into or formed on surface 205 of blade 101, 102, 103 of suitable hardfacing material having a substantially convex curved surface 209′ thereon to deflect chips contacting a surface with a chip breaker 209. Illustrated in FIG. 14D is a chip breaker 211 located on surface 205 of blade 101, 102, 103 comprised of suitable hardfacing material which has been machined, ground, or otherwise shaped into or formed on surface 205 of blade 101, 102, 103 of suitable hardfacing material having substantially two intersecting convex curved surfaces 211′ thereon to deflect chips contacting a surface with a chip breaker 211. The surface 205 of blade 101, 102, 103 further includes a substantially semicircular channel 213 located above the chip breaker 211 to allow drilling fluids to flow thereinto and behind a chip moving along the surface 205 to help cause the chip to break, along with the chip contacting the chip breaker 211 located on surface 205. The blade 101, 102, 103 also includes suitable hardfacing material 215 located on upper surfaces 217 of the blade 101, 102, 103. If desired, the semicircular channel 213 may be filled with hardfacing material 215 with the semicircular channel 213 providing additional contact surface for the hardfacing material 215 on the blade 101, 102, 103. Illustrated in FIG. 14E are semicircular channels 219 located on upper surface 217 of blade 101, 102, 103 for the application of hardfacing material 215 therein to provide additional contact surface for the suitable hardfacing material 215 on the blade. The semicircular channels 219 may extend either transversely across blade 101, 102, 103 or in the same direction as primary cutter pocket 185 or secondary cutter pocket 186 of the blade.

Illustrated in FIG. 10A is suitable hardfacing material 215 on upper surface 217 of blade 101, 102, 103 in the gage area 101′ of the upper surface 217 as well as other areas of the upper surface 217 located between and adjacent primary cutter pockets 185 and secondary cutter pockets 186. The hardfacing material 215 may be applied to any desired thickness on upper surface 217, although a thickness of in the range of about 0.127 cm (0.050 inch) to about 0.762 cm (0.300 inch) is acceptable under most circumstances for use of surfaces 205 and 217 of blades 101, 102, 103 of the expandable reamer apparatus 100 described herein.

The blade track 148 includes a dovetail-shaped groove 179 (FIG. 6) that axially extends along the tubular body 108 on a slanted slope 180 having an acute angle with respect to the longitudinal axis L_8. Each of the blades 101, 102, 103 include a dovetail-shaped rail 181 (FIG. 10) that substantially matches the dovetail-shaped groove 179 of the blade track 148 in order to slidably secure the blades 101, 102, 103 to the tubular body 108. When the push sleeve 115 is influenced by the hydraulic pressure, the blades 101, 102, 103 will be extended upward and outward through a blade passage port 182 into the extended position ready for cutting the formation. The blades 101, 102, 103 are pushed along the blade tracks 148 until the forward motion is stopped by the tubular body 108 or the upper stabilizer block 105 is coupled to the tubular body 108. In the upward-outward or fully extended position, the blades 101, 102, 103 are positioned such that the cutting elements 104 will enlarge a borehole in the subterranean formation by a prescribed amount. When hydraulic pressure provided by drilling fluid flow through expandable reamer apparatus 100 is released, the spring 116 will urge the blades 101, 102, 103 via the push sleeve 115 and the pinned linkage 178 into the retracted position. Should the assembly not readily retract via spring force, when the tool is pulled up the borehole to a casing shoe, the shoe may contact the blades 101, 102, 103 helping to urge or force them down the blade tracks 148, allowing the expandable reamer apparatus 100 to be retrieved from the borehole. In this respect, the expandable reamer apparatus 100 includes a retraction assurance feature to further assist in removing the expandable reamer apparatus from a borehole. The slanted slope 180 of blade tracks 148 in this embodiment of the invention is ten degrees, taken with respect to the longitudinal axis L_8 of the expandable reamer apparatus 100. While the slanted slope 180 of the blade tracks 148 is ten degrees, it may vary from a greater extent to a lesser extent than that illustrated. However, the slanted slope 180 should be less than substantially 35 degrees, for reasons discussed below, to obtain the full benefit of this aspect of the invention. The blades 101, 102, 103, being "locked" into the blade tracks 148 with the dovetail-shaped rails 181 as they are axially driven into the extended position permit looser tolerances, as compared to conventional hydraulic reamers which require close tolerances between the blade pistons and the tubular body to radially drive the blade pistons into their extended positions. Accordingly, the blades 101, 102, 103 are more robust and less likely to bind or fail due to blockage from the fluid. In this embodiment of the invention, the blades 101, 102, 103 have ample clearance in the grooves 179 of the blade tracks 148, such as a 0.0625 cm (1/16 inch) clearance, more or less, between the dovetail-shaped rail 181 and dovetail-shaped groove 179. It is to be recognized that the term "dovetail" when making reference to the groove 179 or the rail 181 is not to be limiting, but is directed broadly toward structures in which each blade 101, 102, 103 is retained with the tubular body 108 of the expandable reamer apparatus 100, while further allowing the blades 101, 102, 103 to transition between two or more positions along the blade tracks 148 without binding or mechanical locking.

Advantageously, the natural, reactive forces acting on the cutting elements 104 on the blades 101, 102, 103 during rotation of expandable reamer apparatus 100 in engaging a formation while reaming a borehole may help to further push the blades 101, 102, 103 in the extended outward direction, holding them with this force in their fully outward or extended position. Drilling forces acting on the cutting elements 104, therefore, along with higher pressure within expandable reamer apparatus 100 creating a pressure differential with that of the borehole exterior to the tool, help to further hold the blades 101, 102, 103 in the extended or outward position. Also, as the expandable reamer apparatus 100 is drilling, the fluid pressure may be reduced when the combination of the slanted slope 180 of the blade tracks 148 is sufficiently shallow, allowing the reactive forces acting on the cutting elements 104 to offset the biasing effect of the biasing spring 116. In this regard, application of hydraulic fluid pressure may be substantially minimized, while drilling as a mechanical advantage allows the reactive forces acting on the cutting elements 104 when coupled with the substantially shallower slanted slope 180 of the blade tracks 148 to provide the requisite reaction force for retaining the blades 101, 102, 103 in their extended position. Conventional reamers having blades extending substantially laterally outward from an extent of 35 degrees or greater (referenced to the longitudinal axis) requires the full, and continued, application of hydraulic pressure to maintain the blades in an extended position. Accordingly and unlike the case with conventional expandable reamers, the blades 101, 102, 103 of expandable reamer apparatus 100 have a tendency to open as opposed to tending to close when reaming a borehole. The direction of the net cutting force and, thus, of the reactive force may be adjusted by altering the backrake, exposure and siderake of the cutting elements 104 to better achieve a net force tending to move the blades 101, 102, 103 to their fullest outward extent.

Another advantage of a so-called “shallow track,” i.e., the substantially small slanted slope 180 having an acute angle, is greater spring force retraction efficiency. Improved retraction efficiency enables improved or customized spring rates to be utilized to control the extent of the biasing force by the spring 116, such as selecting the biasing force required to be overcome by hydraulic pressure to begin to move or fully extend the blades 101, 102, 103. Also, with improved retraction efficiency greater assurance of blade retraction is assured when the hydraulic fluid pressure is removed the expandable reamer apparatus 100. Optionally, the spring 116 may be preloaded when the expandable reamer apparatus 100 is in the initial or retracted positions, allowing a minimal amount of retraction force to be constantly applied.

Another advantage provided by the blade tracks 148 is the unitary design of each "dovetail-shaped" groove 179, there being one groove 179 for receiving one of the oppositely opposed "dovetail-shaped" rails 181 of the guides 187 on each side of the blades 101, 102, 103. In conventional expandable reamers, each side of a movable blade includes a plurality of ribs or channels for being received into opposing channels or ribs of the reamer body, respectively, such arrangements being highly prone to binding when the blades are subjected to operational forces and pressures. In addition to ease of blade extension and retraction without binding along or in the blade track 148, the single rail and cooperating groove design provides non-binding structural support for blade operation, particularly when engaging a formation while reaming.

In addition to the upper stabilizer block 105, the expandable reamer apparatus 100 also includes a mid stabilizer block 106 and a lower stabilizer block 107 (see FIG. 1). Optionally, the mid stabilizer block 106 and the lower stabilizer block 107 may be combined into a unitary stabilizer block. The stabilizer blocks 105, 106, 107 help to center the expandable reamer apparatus 100 in the drill hole while being run into position through a casing or liner string and also while drilling and reaming the borehole. As mentioned above, the upper stabilizer block 105 may be used to stop or limit the forward motion of the blades 101, 102, 103, determining the extent to which the blades 101, 102, 103 may engage a borehole while drilling. The upper stabilizer block 105, in addition to providing a back stop for limiting the lateral extent of the blades, may provide for additional stability when the blades 101, 102, 103 are retracted and the expandable reamer apparatus 100 of a drill string is positioned within a borehole in an area where an expanded hole is not desired while the drill string is rotating.

Advantageously, the upper stabilizer block 105 may be mounted, removed and/or replaced by a technician, particularly in the field, allowing the extent to which the blades 101, 102, 103 engage the borehole to be readily increased or decreased to a different extent than illustrated. Optionally, it is recognized that a stop associated on a track side of the upper stabilizer block 105 may be customized in order to arrest the extent to which the blades 101, 102, 103 may laterally extend when fully positioned to the extended position along the blade tracks 148. The stabilizer blocks 105, 106, 107 may include hardfaced bearing pads (not shown) to provide a surface for contacting a wall of a borehole while stabilizing the apparatus therein during a drilling operation.

Also, the expandable reamer apparatus 100 may include tungsten carbide nozzles 110 as shown in FIG. 9. The nozzles 110 are provided to cool and clean the cutting elements 104 and clear debris from blades 101, 102, 103 during drilling. The nozzles 110 may include an O-ring seal 140 between each nozzle 110 and the tubular body 108 to provide a seal between the two components. As shown, the nozzles 110 are configured to direct drilling fluid towards the blades 101, 102, 103 in the downhole direction 157, but may be configured to direct fluid laterally or in the uphole direction 159.

The expandable reaming apparatus, or reamer, 100 is now described in terms of its operational aspects. Reference may be made to FIGS. 17-23, in particular, and optionally to FIGS. 1-16, as desirable. The expandable reamer apparatus 100 may be installed in a bottomhole assembly above a pilot bit and, if included, above or below the measurement while drilling (MWD) device and incorporated into a rotary steerable system (RSS) and rotary closed loop system (RCLS), for example. Before "triggering" the expandable reamer apparatus 100, the expandable reamer apparatus 100 is maintained in an initial, retracted position as shown in FIG. 17. For instance, the traveling sleeve 128 within the expandable reamer apparatus 100 isolates the fluid flow path and prevents inadvertent extension of blades 101, 102, 103, as previously described, and is retained by the shear assembly 150 with shear screws 127 secured to the uplock sleeve 124 which is attached to the tubular body 108. While the traveling sleeve 128 is held in the initial position, the blade actuating means is prevented from directly actuating the blades 101, 102, 103 whether acted upon by biasing forces or hydraulic forces. The traveling sleeve 128 has, on its lower end, an enlarged end piece, the seat stop sleeve 130. This larger diameter seat stop sleeve 130 holds the dogs 166 of the lowlock sleeve 117 in a secured position, preventing the push sleeve 115 from moving upward under affects of differential pressure and activating the blades 101, 102, 103. The latch dogs 166 lock the latch or expandable detent 168 into an annular groove 167 in the inner bore 151 of the tubular body 108. When it is desired to trigger the expandable reamer apparatus 100, drilling fluid flow is momentarily ceased, if required, and a ball 147, or other fluid restricting element, is dropped into the drill string and pumping of drilling fluid resumed. The ball 147 moves in the downhole direction 157 under the influence of gravity and/or the flow of the drilling fluid, as shown in FIG. 18. After a short time the ball 147 reaches a ball seat of the ball trap sleeve 129, as shown in FIG. 19. The ball 147 stops drilling fluid flow and causes pressure to build above it in the drill string. As the pressure builds, the ball 147 may be further seated into or against the plug 131, which may be made of, or lined with, a resilient material such as tetrafluoroethylene (TFE).

Referring to FIG. 20, at a predetermined pressure level, set by the number and individual shear strengths of the shear screws 127 (made of brass or other suitable material) installed initially in the expandable reamer apparatus 100, the shear screws 127 will fail in the shear assembly 150 and allow the traveling sleeve 128 to unseal and move downward. As the traveling sleeve 128 with the larger end of the seat stop sleeve 130 moves downward, the latch dogs 166 of the lowlock sleeve 117 are free to move inward toward the smaller diameter of the traveling sleeve 128 and become free of the tubular body 108.

Thereafter, as illustrated in FIG. 21, the lowlock sleeve 117 is attached to the pressure-activated push sleeve 115 which now moves upward under fluid pressure influence as fluid is allowed to pass through the fluid ports 173, exposed as the traveling sleeve 128 moves downward. As the fluid pressure is increased, the biasing force of the spring 116 is overcome, allowing the push sleeve 115 to move in the uphole direction 159. The push sleeve 115 is attached to the yoke 114, which is attached by pins and linkage assembly 178 to the three blades 101, 102, 103, which are now moved upwardly by the push sleeve 115. In moving upward, the blades 101, 102, 103 each follow a ramp or blade track 148 to which they are mounted, via a type of modified square dovetail-shaped groove 179 (shown in FIG. 2), for example.

As shown in FIG. 22, the stroke of the blades 101, 102, 103 is stopped in the fully extended position by upper hardfaced pads on the upper stabilizer block 105, for example. Optionally, as mentioned herein above, a customized stabilizer block may be assembled to the expandable reamer apparatus 100 prior to drilling in order to adjust and limit the extent to which the blades 101, 102, 103 may extend. With the blades 101, 102, 103 in the extended position, reaming a borehole may commence.

As reaming takes place with the expandable reamer apparatus 100, the hardfaced pads on the lower and mid stabilizer blocks 106, 107 help to stabilize the tubular body 108 as the cutting elements 104 of the blades 101, 102, 103 ream a larger borehole and the hardfaced pads on the upper stabilizer block 105 also help to stabilize the top of the expandable reamer apparatus 100 when the blades 101, 102 and 103 are in the retracted position.

After the traveling sleeve 128 with the ball 147 moves downward, it comes to a stop with the flow bypass or fluid ports 173 located above the ball 147 in the traveling sleeve 128 exiting against the inside wall 184 of the hardfaced protect sleeve 121, which helps to prevent or minimize erosion damage from drilling fluid flow impinging thereupon. The drilling fluid flow may then continue down the bottomhole assembly, and the upper end of the traveling sleeve 128 becomes "trapped," i.e., locked, between the one or more ears 163 of the uplock sleeve 124 and the shock absorbing member 125 of the seal sleeve 126, and the lower end of the traveling sleeve 128 is laterally stabilized by the stabilizer sleeve 122.

When drilling fluid pressure is released, the spring 116 will help drive the lowlock sleeve 117 and the push sleeve 115 with the attached blades 101, 102, 103 back downwardly and inwardly substantially to their original or initial position into the retracted position, see FIG. 23. However, since the traveling sleeve 128 has moved to a downward locked position, the larger diameter seat stop sleeve 130 will no longer hold the dogs 166 out and in the annular groove 167 and, thus, the latch or lowlock sleeve 117 stays unlatched and subjected to pressure differentials for subsequent operation or activation.

Whenever drilling fluid flow is re-established in the drill pipe and through the expandable reamer apparatus 100, the push sleeve 115, with the yoke 114 and blades 101, 102, 103, may move upward with the blades 101, 102, 103 following the ramps or blade tracks 148 to again cut/ream the prescribed larger diameter in a borehole. Whenever drilling fluid flow is stopped, i.e., the differential pressure falls below the restoring force of the spring 116, the blades 101, 102, 103 retract, as described above, via the spring 116.

In aspects of the invention, the expandable reamer apparatus 100 overcomes disadvantages of conventional reamers. For example, one conventional hydraulic reamer utilized pressure from inside the tool to apply force against cutter pistons which moved radially outward. It is felt by some that the nature of the conventional reamer allowed misaligned forces to cock and jam the pistons, preventing the springs from retracting them. By providing the expandable reamer apparatus 100, which slides each of the blades up a relatively shallow-angled ramp, higher drilling forces may be used to open and extend the blades to their maximum position while transferring the forces through to the upper hardface pad stop with no damage thereto and subsequently allowing the spring to retract the blades thereafter without jamming or cocking.

The expandable reamer apparatus 100 includes blades that, if not retracted by the spring, will be pushed down the ramp of the track by contact with the borehole wall and the casing and allow the expandable reamer apparatus 100 to be pulled through the casing, providing a kind of fail-safe function.

The expandable reamer apparatus 100 is not sealed around the blades 101, 102, 103 and does not require seals thereon, such as the expensive or custom made seals used in some conventional expandable reamers.

The expandable reamer apparatus 100 includes clearances of ranging from 0.0254 cm (0.010 of an inch) to 0.0762 cm (0.030 of an inch) between adjacent parts having dynamic seals therebetween. The dynamic seals are all conventional, circular seals. Moreover, the sliding mechanism or actuating means, which includes the blades in the tracks, includes clearances ranging from 0.127 cm (0.050 of an inch) to 0.254 cm (0.100 of an inch), particularly about the dovetail portions. Clearances in the expandable reamer apparatus 100, the blades 101, 102, 103 and the blade tracks 148 may vary to a somewhat greater extent or a lesser extent than indicated herein. The larger clearances and tolerances of the parts of expandable reamer apparatus 100 promote ease of operation, particularly with a reduced likelihood of binding caused by particulates in the drilling fluid and formation debris cut from the borehole wall.

Additional aspects of the expandable reamer apparatus 100 are now provided:

The blade 101 may be held in place along the blade track 148 (shown in FIG. 2) by guides 187. The blade 101 includes mating guides 187 as shown in FIGS. 10-14. Each mating guide 187 is comprised of a single rail 181 oppositely located on each side of the blade 101 and includes an included angle θ that is selected to prevent binding with the mating guides 187 of the blade track 148. The included angle θ of the rails 181 of the blade 101 in this embodiment is 30 degrees such that the blade 101 is prone to move away from or provide clearance about the blade track 148 in the tubular body 108 when subjected to the hydraulic pressure.

The blades 101, 102, 103 are attached to a yoke 114 with the linkage assembly, as described herein, which allow the blades 101, 102, 103 to move upward and radially outward along the 5° to 25° (degree) ramp, in this embodiment of the invention, as the actuating means, i.e., the yoke 114 and push sleeve 115, moves axially upward. The link of the linkage assembly is pinned to both the blades 101, 102, 103 and the yoke 114 in a similar fashion. The linkage assembly, in addition to allowing the actuating means to directly extend and retract the blades 101, 102, 103 substantially in the longitudinal or axial direction, enables the upward and radially outward extension of the blades 101, 102, 103 by rotating through an angle, approximately 30-60 degrees in this embodiment of the invention, during the direct actuation of the actuating means and the blades 101, 102, 103.

In case the blades 101, 102, 103 somehow do not readily move back down the ramp of the blade tracks 148 under biasing force from the retraction spring 116, then as the expandable reamer apparatus 100 is pulled from the borehole, contact with the borehole wall will bump the blades 101, 102, 103 down the slanted slope 180 of the blade tracks 148. If needed, the blades 101, 102, 103 of the expandable reamer apparatus 100 may be pulled up against the casing, which may push the blades 101, 102, 103 further back into the retracted position thereby allowing access and removal of the expandable reamer apparatus 100 through the casing.

In other embodiments of the invention, the traveling sleeve 128 may be sealed to prevent fluid flow from exiting the tool through the blade passage ports 182 (FIG. 2), and after triggering, the seal may be maintained.

The nozzles 110, as mentioned above, may be directed in the direction of flow through the expandable reamer apparatus 100 from within the tubular body 108 downward and outward radially to the annulus between tubular body 108 and a borehole. Directing the nozzles 110 in such a downward direction causes counterflow as the flow exits the nozzle 110 and mixes with the annular moving counter flow returning up the borehole and may improve blade cleaning and cuttings removal. The nozzles 110 are directed at the cutting elements 104 of the blades 101, 102, 103 for maximum cleaning, and may be directionally optimized using computational fluid dynamics ("CFD") analysis.

The expandable reamer apparatus 100 may include a lower saver sub 109 shown in FIG. 4 that connects to the lower box connection of the tubular body 108. Allowing the tubular body 108 to be a single piece design, the saver sub 109 enables the connection between the two to be stronger (due to higher make-up torque) than a conventional two-piece tool having an upper and a lower connection. The saver sub 109, although not required, provides for more efficient connection to other downhole equipment or tools.

Still other aspects of the expandable reamer apparatus 100 are now provided:

The shear screws 127 of the shear assembly 150, retaining the traveling sleeve 128 and the uplock sleeve 124 in the initial position, are used to provide or create a trigger, releasing when pressure builds to a predetermined value. The predetermined value at which the shear screws 127 shear under drilling fluid pressure within expandable reamer apparatus 100 may be 1000 psi, for example, or even 2000 psi. It is recognized that the pressure may range to a greater or lesser extent than presented herein to trigger the expandable reamer apparatus 100. Optionally, it is recognized that a greater pressure at which the shear screws 127 shear may be provided to allow the spring 116 to be conditionally configured and biased to a greater extent in order to further provide desired assurance of blade retraction upon release of hydraulic fluid.

Optionally, one or more of the blades 101, 102, 103 may be replaced with stabilizer blocks having guides and rails as described herein for being received into dovetail-shaped grooves 179 of the blade track 148 in the expandable reamer apparatus 100, which may be used as an expandable concentric stabilizer rather than a reamer, which may further be utilized in a drill string with other concentric reamers or eccentric reamers.

Optionally, the blades 101, 102, 103 may each include one row or three or more rows of cutting elements 104 rather than the two rows of cutting elements 104 shown in FIG. 2. Advantageously, two or more rows of cutting elements 104 help to extend the life of the blades 101, 102, 103 particularly when drilling in hard formations.

FIG. 24 shows a cross-sectional view of an embodiment of an expandable reamer apparatus 10 having a measurement device 20 in accordance with another embodiment of the invention. The measurement device 20 provides an indication of the distance between the expandable reamer apparatus 10 and a wall of a borehole being drilled, enabling a determination to be made as to the extent at which the expandable reamer apparatus 10 is enlarging a borehole. As shown, the measurement device 20 is mounted to the tubular body 108 generally in a direction perpendicular to the longitudinal axis L_8 of the expandable reamer apparatus 10. The measurement device 20 is coupled to a communication line 30 extending through a tubular body 108 of the expandable reamer apparatus 10 that includes an end connection 40 at the upper end 191 of the expandable reamer apparatus 10. The end connection 40 may be configured for connection compatibility with particular or specialized equipment, such as a MWD communication subassembly. The communication line 30 may also be used to supply power to the measurement device 20. The measurement device 20 may be configured for sensing, analyzing and/or determining the size of a borehole, or it may be used purely for sensing, in which the size of a borehole may be analyzed or determined by other equipment as is understood by a person of skill in the MWD art, thereby providing a substantially accurate determination of a borehole size. The measurement device 20 becomes instrumental in determining when the expandable reamer apparatus 10 is not drilling at its intended diameter, allowing remedial measures to be taken rather than drilling for extended durations or hundreds/thousands of meters/feet to enlarge a borehole, which would then have to be re-reamed.

The measurement device 20 may be part of a nuclear based measurement system such as disclosed in U.S. Patent No. 5,175,429 to Hall et al., assigned to the assignee of the invention herein disclosed. The measurement device 20 may also include sonic calipers, proximity sensors, or other sensors suitable for determining a distance between a wall of a borehole and the expandable reamer apparatus 10. Optionally, the measurement device 20 may be configured, mounted and used to determine the position of the movable blades and/or bearing pads of the expandable reamer apparatus 20, wherein the reamed minimum borehole diameter may be inferred from such measurements. Similarly, a measurement device may be positioned within the movable blade so as to be in contact with or proximate to the formation on the borehole wall when the movable blade is actuated to its outermost fullest extent.

FIG. 25 shows a cross-sectional view of a motion limiting member 210 for use with an expandable reamer apparatus 200 for limiting the extent to which blades may extend outwardly. As discussed above with respect to the upper stabilizer blocks 105 including a back stop for limiting the extent to which the blades may extend upwardly and outwardly along the blade tracks, the motion limiting member 210 may be used to limit the extent in which the actuating means, i.e., the push sleeve 115, may extend in the axial uphole direction 159. The motion limiting member 210 may have a cylindrical sleeve body 212 positioned between an outer surface of the push sleeve 115 and the inner bore 151 of the tubular body 108. As shown, the spring 116 is located between the motion limiting member 210 and the tubular body 108 while a base end 210′ of the motion limiting member 210 is retentively retained between the spring 116 and the retaining ring 113. When the push sleeve 115 is subjected to motion, such as by hydraulic fluid pressure as described hereinabove, the spring 116 will be allowed to compress in the uphole direction 159 until its motion is arrested by the motion limiting member 210 which prevents the spring 116 and the push sleeve 115 from further movement in the uphole direction 159. In this respect, the blades of the expandable reamer apparatus 200 are prevented from extending beyond the limit set by the motion limiting member 210.

As shown in FIG. 26, another motion limiting member 220 for use with an expandable reamer apparatus 200 is configured with a spring box body 222 having an open cylindrical section 223 and a base end 221. A portion of the spring 116 is contained within the open cylindrical section 223 of the spring box body 222 with the base end 221 resting between the spring 116 and an upper end of the lowlock sleeve 117. The motion of spring 116 and the push sleeve 115 is arrested when the spring box body 222 is extended into impinging contact with the retaining ring 113 or a ledge or lip 188 located in the inner bore 151 of the tubular body 108.

While the motion limiting members 210 and 220 (shown in FIGS. 25 and 26, respectively), are generally described as being cylindrical, they may have other shapes and configurations, for example, a pedestal, leg or elongated segment, without limitation. In a very broad sense, the motion limiting member allows the extent of axial movement to be arrested to varying degrees for an assortment of application uses, particularly when different boreholes are to be reamed with a common expandable reamer apparatus requiring only minor modifications thereto.

In other embodiments, the motion limiting members 210 or 220 may be simple structures for limiting the extent to which the actuating means may extend to limit the motion of the blades. For example, a motion limiting member may be a cylinder that floats within the space between the outer surface of the push sleeve 115 and the inner bore 151 of the tubular body 108, either between the spring 116 and the push sleeve 115 or the spring 116 and the tubular body 108.

The expandable reamer apparatus 100, as described above with reference to FIGS. 1-23, provides for robust actuation of the blades 101, 102, 103 along the same non-binding path (in either direction), which is a substantial improvement over conventional reamers having a piston integral to the blades thereof to accumulate hydraulic pressure to operate it outward and thus requiring a differently located forcing mechanism such as springs to retract the blades back inward. In this respect, the expandable reamer apparatus 100 includes activation means, i.e., the linkage assembly, the yoke 114, the push sleeve 115, to be the same components for extending and retracting the blades 101, 102, 103, allowing the actuating force for moving the blades to lie along the same path, but in opposite directions. With conventional reamers, the actuation force to extend the blades is not guaranteed to lie exactly in opposite directions and at least not along the same path, increasing the probability of binding. The expandable reamer apparatus herein described overcomes deficiencies associated with conventional reamers.

In another aspect of the invention, the expandable reamer apparatus 100 drives the actuating means, i.e., the push sleeve 115, axially in a first direction while forcing the blades 101, 102, 103 to move to the extended position (the blades being directly coupled to the push sleeve 115 by a yoke 114 and linkage assembly). In the opposite direction, the push sleeve 115 directly retracts the blades 101, 102, 103 by pulling, via the yoke 114 and linkage assembly. Thus, activation means provides for the direct extension and retraction of the blades 101, 102, 103, irrespective of the biasing spring 116 or the hydraulic fluid as conventionally provided.

While particular embodiments of the invention have been shown and described, numerous variations and other embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention only be limited in terms of the appended claims and their legal equivalents.

CLAIMS

What is claimed is:

1. An expandable reamer apparatus (100) for enlarging a borehole in a subterranean formation, characterized in that:

a tubular body (108) having a longitudinal axis (L_8), an inner bore, an outer surface, and at least one track (148) within the tubular body (108) between the inner bore and the outer surface, the track (148) sloped upwardly and outwardly at an acute angle to the longitudinal axis (L_8);

a drilling fluid flow path extending through the inner bore;

one or more blades (101, 102, 103) each having at least one cutting element (104) configured to remove material from a subterranean formation during reaming, at least one blade (101, 102, 103) slidably coupled to the at least one track (148) of the tubular body (108), at least one blade (101, 102, 103) having hardfacing material (215) thereon; and

a push sleeve (115) disposed within the inner bore of the tubular body (108) and coupled to the at least one blade (101, 102, 103), the push sleeve (115) configured to move axially upward responsive to a pressure of drilling fluid passing through the drilling fluid flow path to extend the at least one blade (101, 102, 103) along the at least one track (148) and into an extended position.

2. The expandable reamer apparatus (100) of claim 1, characterized in that wherein at least one blade (101, 102, 103) has a front surface (205) having hardfacing material (215) thereon.

3. The expandable reamer apparatus (100) of claim 2, characterized in that wherein the hardfacing material (215) comprising a material having one of a curved surface, a substantially square cross-section, a substantially convex surface, and having two substantially convex surfaces.

4. The expandable reamer apparatus (100) of claim 2, characterized in that wherein at least one of the blades (101, 102, 103) comprises a blade having a gage portion (101′) having hardfacing material (215) located on a portion thereof.

5. The expandable reamer apparatus (100) of claim 2, characterized in that wherein at least one of the blades (101, 102, 103) comprises a blade having a front surface (205) having a channel (213) located in a portion thereof, a portion of the channel (213) containing hardfacing material (215) therein.

6. The expandable reamer apparatus (100) of claim 1, characterized in that wherein at least one of the blades (101, 102, 103) comprises a blade having an upper surface (217) having at least one channel (219) therein, at least a portion of at least one channel (219) containing hardfacing material (215) therein.

7. The expandable reamer apparatus (100) of claim 1, further characterized in that a biasing element (116) disposed within the inner bore of the tubular body (108), in contact with the push sleeve (115) and oriented to bias the push sleeve (115) in an axial downward direction to retract the at least one blade (101, 102, 103) along the at least one track (148) and into a retracted position when the push sleeve (115) is not subjected to force or pressure of drilling fluid.

8. The expandable reamer apparatus (100) of claim 1, characterized in that wherein the at least one blade (101, 102, 103) is directly coupled to the push sleeve (115) by a linkage assembly (178).

9. The expandable reamer apparatus (100) of claim 1, further characterized in that a guide structure for positionally retaining and guiding the at least one blade (101, 102, 103) within the at least one track (148).

10. The expandable reamer apparatus (100) of claim 1, further characterized in that a motion limiting member coupled between the tubular body (108) and the push sleeve (115) to limit the axial extent of the push sleeve (115).

11. The expandable reamer apparatus (100) of claim 10, further characterized in that a traveling sleeve (128) positioned within the inner bore of the tubular body (108) and configured to selectively isolate the push sleeve (115) and blades (101, 102, 103) from exposure to force or pressure of drilling fluid, the traveling sleeve (128) axially retained in an initial position by a shear assembly (150) within the inner bore of the tubular body (108).

12. The expandable reamer apparatus (100) of claim 11, characterized in that wherein the push sleeve (115) is axially retained in an initial position by a lowlock assembly (117) coupled within the tubular body (108) and comprising a lower end of the traveling sleeve (128), and the push sleeve (115) is axially transitionable between the extended position and a retracted position after the traveling sleeve (128) has axially transitioned sufficiently to release the push sleeve (115) from the lowlock assembly (117).

13. The expandable reamer apparatus (100) of claim 12, further characterized in that an uplock sleeve (124) for axially retaining the traveling sleeve upon sufficient travel within the tubular body (108) and upon exposing the push sleeve (115) to exposure of force or pressure of drilling fluid within the flow path.

14. The expandable reamer apparatus (100) of claim 1, further characterized in that a measurement device (20) for determining a diameter of the enlarged borehole.

15. The expandable reamer apparatus (100) of claim 12, further characterized in that a stabilizer sleeve (122) coupled to the inner bore of a lower end of the tubular body (108) for receiving a lower end of the traveling sleeve (128).

16. An expandable reamer apparatus (100) for enlarging a borehole in a subterranean formation, characterized in that:

a tubular body (108) having a longitudinal axis (L_8), an inner bore, an outer surface, a plurality of upwardly and outwardly sloping tracks (148) within the tubular body (108) between the inner bore and the outer surface at an acute angle to the longitudinal axis(L_8);

a drilling fluid flow path extending through the tubular body (108) for conducting drilling fluid therethrough;

a plurality of circumferentially spaced, generally radially and longitudinally extending blades (101, 102, 103), each blade (101, 102, 103) slidably engaged with one of the plurality of tracks (148) , carrying at least one cutting structure thereon and movable along its associated track between an extended position and a retracted position, each blade having hardfacing material (215) thereon; and

actuation structure (115) positioned within the tubular body and configured to directly effect movement of the blades (101, 102, 103) in the tracks (148) in opposing directions responsive to a pressure of drilling fluid within the flow path and an opposing force.

17. An expandable reamer apparatus (100) for enlarging a borehole in a subterranean formation, characterized in that:

a tubular body (108) having a longitudinal axis(L_8), an outer surface, and a track (148) within the tubular body (108), the track (148) sloped upwardly and outwardly at an acute angle to the longitudinal axis(L_8);

a drilling fluid flow path extending through an inner bore of the tubular body (108);

a blade (101, 102, 103) having at least one cutting element (104) configured to remove material from a subterranean formation during reaming and slidably coupled to the track (148), the blade 9101, 102, 103) having hardfacing (215) material on a portion thereof;

a push sleeve (115) disposed within the inner bore of the tubular body (108) and directly coupled to the blade (101, 102, 103), the push sleeve (115) configured to move axially upward responsive to a pressure of drilling fluid passing through the inner bore to extend the blade (101, 102, 103) along the track (148); and

a traveling sleeve (128) coupled to an inner bore of the push sleeve (115) and configured to selectively allow communication of drilling fluid passing through the inner bore with the push sleeve (115) to effect axial movement thereof and to secure the push sleeve (115) in an initial position prior to movement thereof.

18. An expandable reamer apparatus (100) for enlarging a borehole in a subterranean formation, characterized in that:

a tubular body (108) having a longitudinal axis (L_8), and at least one track (148) within a wall of the tubular body (108) sloped upwardly and outwardly at an acute angle to the longitudinal axis (L_8);

a drilling fluid flow path extending through an inner bore of the tubular body (108);

at least one blade (101, 102, 103) having at least one cutting element (104) configured to remove material from a subterranean formation during reaming, the at least one blade (101, 102, 103) slidably coupled to the at least one track (148), the at least one blade (101, 102, 103) having hardfacing material (215) on a portion thereof;

a push sleeve (115) disposed within the inner bore of the tubular body (108) and directly coupled to the at least one blade (101, 102, 103), the push sleeve (115) configured to move axially upward responsive to a pressure of drilling fluid passing through the inner bore to extend the at least one blade (101, 102, 103) along the track (148);

a longitudinal biasing (116) element disposed within the inner bore of the tubular body (108) and in contact with the push sleeve (115); and

a motion limiting member coupled between the tubular body (108) and the push sleeve (115) to limit an extent of axial movement of the push sleeve (115) responsive to the pressure.

19. An expandable reamer apparatus (100) for enlarging a borehole in a subterranean formation, characterized in that:

a body (108) having a longitudinal axis (L_8);

a drilling fluid flow path extending through the body (108) for conducting drilling fluid therethrough;

a plurality of blades (101, 102, 103) carried by the body (108) at an acute angle relative to the longitudinal axis (L_8), each blade (101, 102, 103) carrying at least one cutting structure (104) thereon, at least one blade having hardfacing material (215) on a portion thereof; and

an actuation means (115) positioned within the body (108) and configured to directly actuate the plurality of blades (101, 102, 103) between an extended position and a retracted position in respective response to a pressure provided by the drilling fluid within the flow path and an opposing force.

20. A method of activating a downhole apparatus (100) within a borehole of a subterranean formation, characterized in that:

disposing a downhole apparatus (100) within the subterranean formation having a plurality of blades (101, 102, 103), at least one blade (101, 102, 103) having hardfacing material (215) on a portion thereof, the downhole apparatus (100) including a restriction element trap (129) configured for retentively receiving a restriction element (147) and positioned within a bore of an actuation element (115), positioned for movement within a bore of the downhole apparatus (100) and configured to selectively isolate an operable component from drilling fluid pressure within the downhole apparatus (100) prior to the movement;

flowing drilling fluid through the downhole apparatus via a flow path;

disposing a restriction element (147) into the drilling fluid;

receiving the restriction element (147) in the restriction element trap (129) carried by flowing drilling fluid through the flow path to occlude the flow path;

releasing the actuation element (115) for movement during or after occlusion of the fluid flow path; and effecting movement of the blades (101, 102, 103) responsive to a pressure of drilling fluid within the flow path causing the plurality of blades to move outwardly in the borehole for the hardfacing material (215) reducing wear of the at least one blade (101, 102, 103) during operation of the downhole apparatus (100).

21. The method of claim 20, characterized in that wherein receiving the restriction element (147) in the restriction element trap (129) is effected at a drilling fluid pressure substantially lower than a drilling fluid pressure required for releasing the actuation element (115).

22. A method of engaging a borehole of a subterranean formation using a downhole apparatus (100), characterized in that:

disposing a downhole apparatus (100) within the subterranean formation having a plurality of blades (101, 102, 103), at least one blade (101, 102, 103) having a cutting element (104) thereon for engaging the borehole and chip breaking material (207) on a portion thereof for deflecting material from the borehole removed by the cutting element (104);

flowing drilling fluid through the downhole apparatus (100) via a flow path;

effecting movement of the blades (101, 102, 103) responsive to a pressure of drilling fluid within the flow path causing the plurality of blades (101, 102, 103) to move outwardly in the borehole for the cutting element (104) to engage the borehole;

rotating the downhole apparatus (100) for the cutting element (104) to remove a portion of the subterranean formation; and

deflecting from the at least one blade (101, 102, 103) at least a portion of the portion of subterranean formation removed by the cutting element (104) using the chip breaking material (207) on the at least one blade (101, 102, 103).

23. A method of reducing wear on a blade (101, 102, 103) of a downhole apparatus (100) from the cuttings of a subterranean formation characterized in that:

disposing a downhole apparatus (100) within the subterranean formation having a plurality of blades (101, 102, 103), at least one blade (101, 102, 103) having a cutting element (104) thereon for engaging the borehole and chip breaking material (215) on a portion thereof for deflecting material from the borehole removed by the cutting element (104);

effecting movement of the plurality of blades (101, 102, 103) outwardly in the borehole for the cutting element (104) to engage the borehole;

rotating the downhole apparatus (1000 for the cutting element (104) to remove a portion of the subterranean formation; and

deflecting at least a portion of the subterranean formation removed by the cutting element (104) using the chip breaking material (215) on the at least one blade (101, 102, 103).

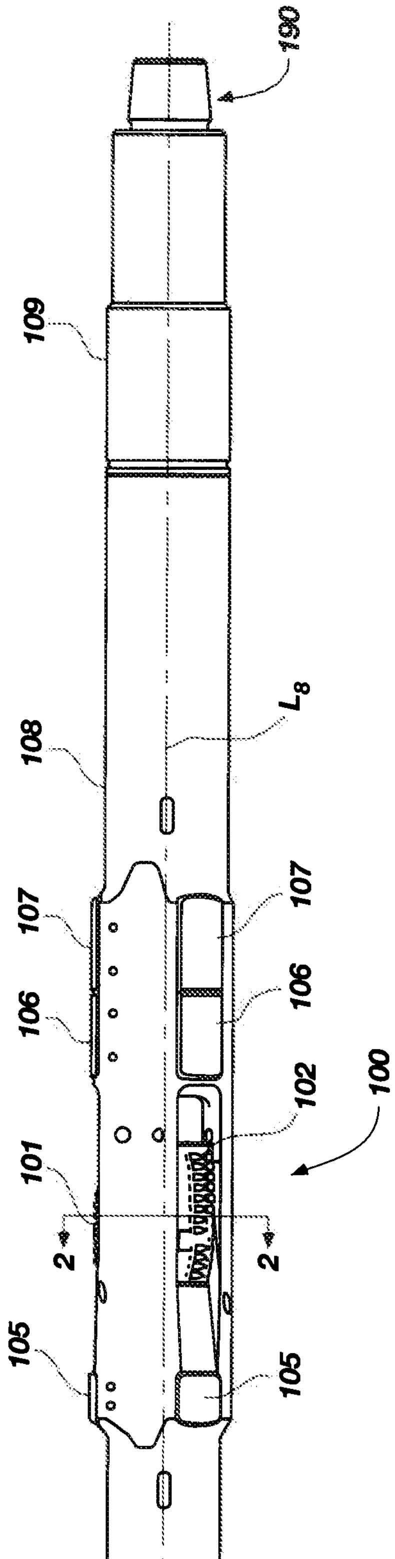


FIG. 1

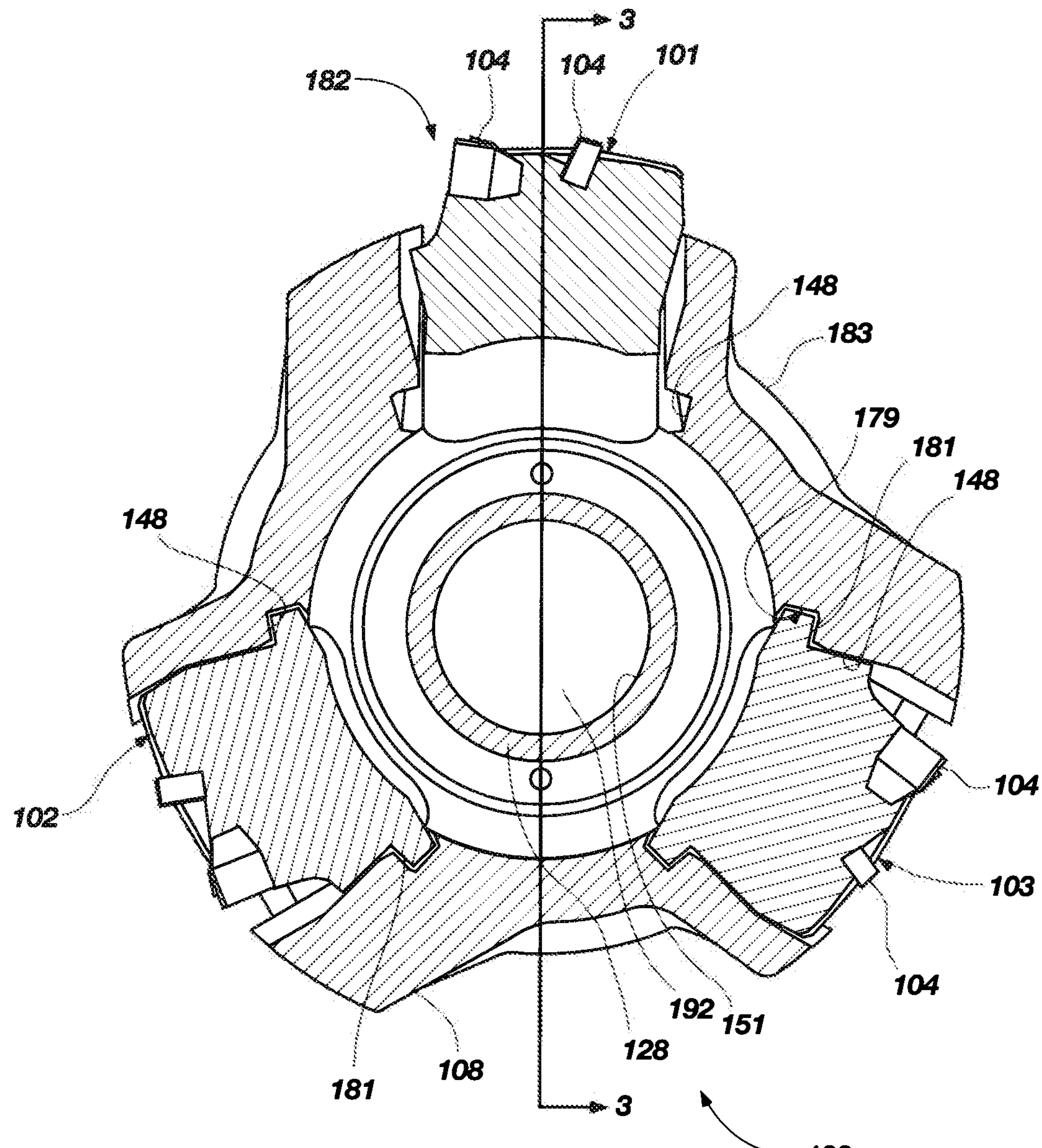

3
104
104
101
182
148
183
179
181
148
148
102
104
103
104
192
151
128
181
108
3
100

FIG. 2

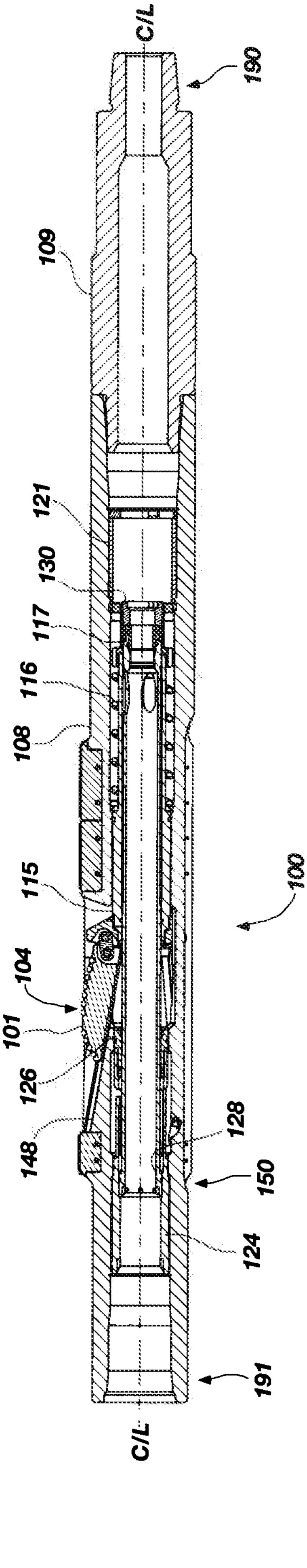

C/L
190
109
121
130
117
116
108
115
104
101
126
148
100
128
150
124
191
C/L

FIG. 3

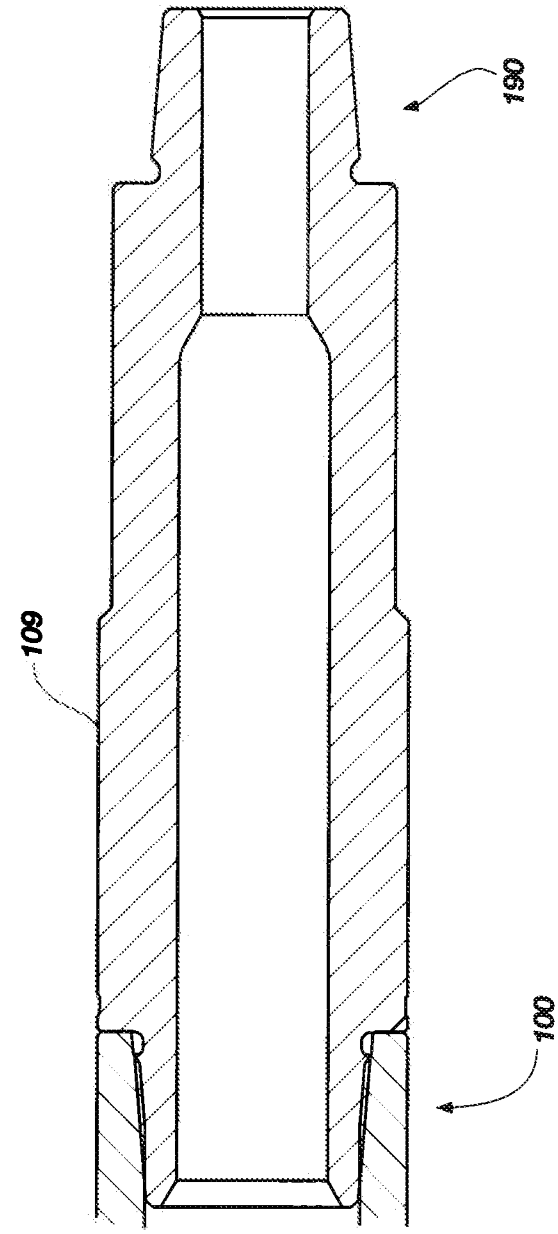


FIG. 4

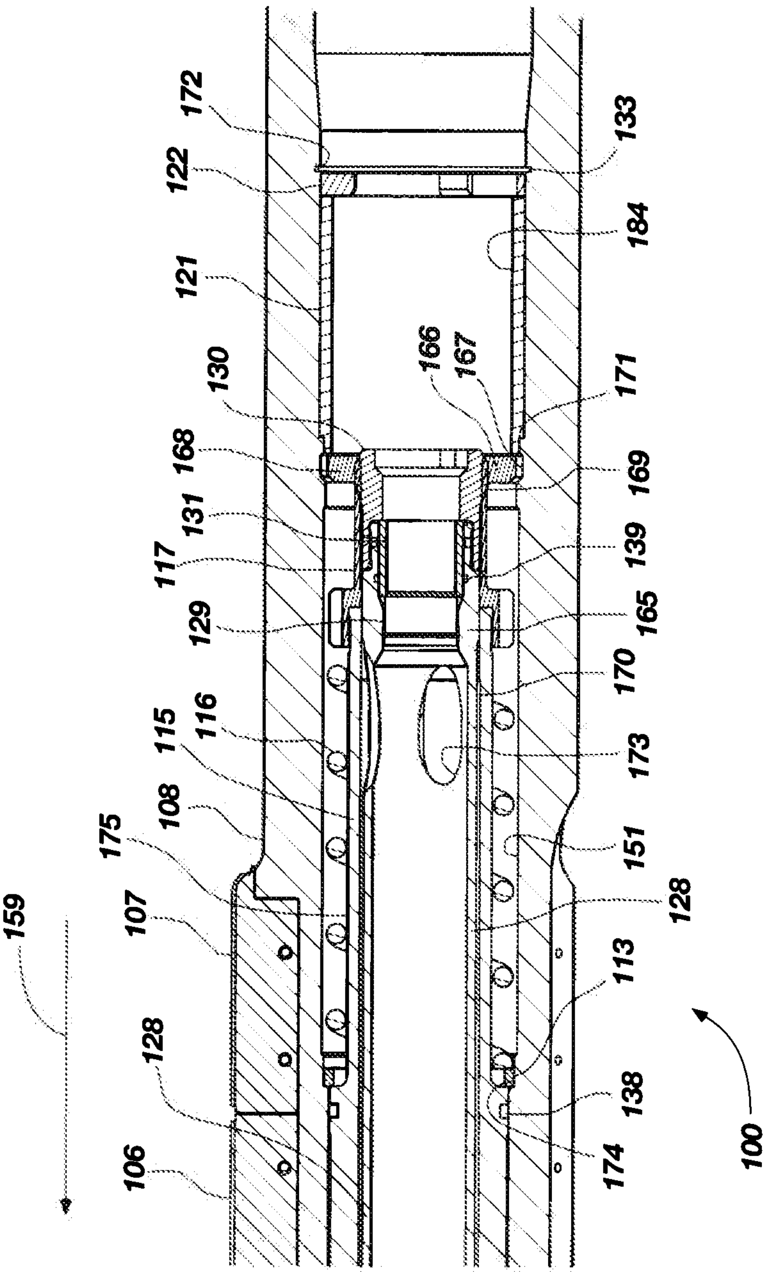
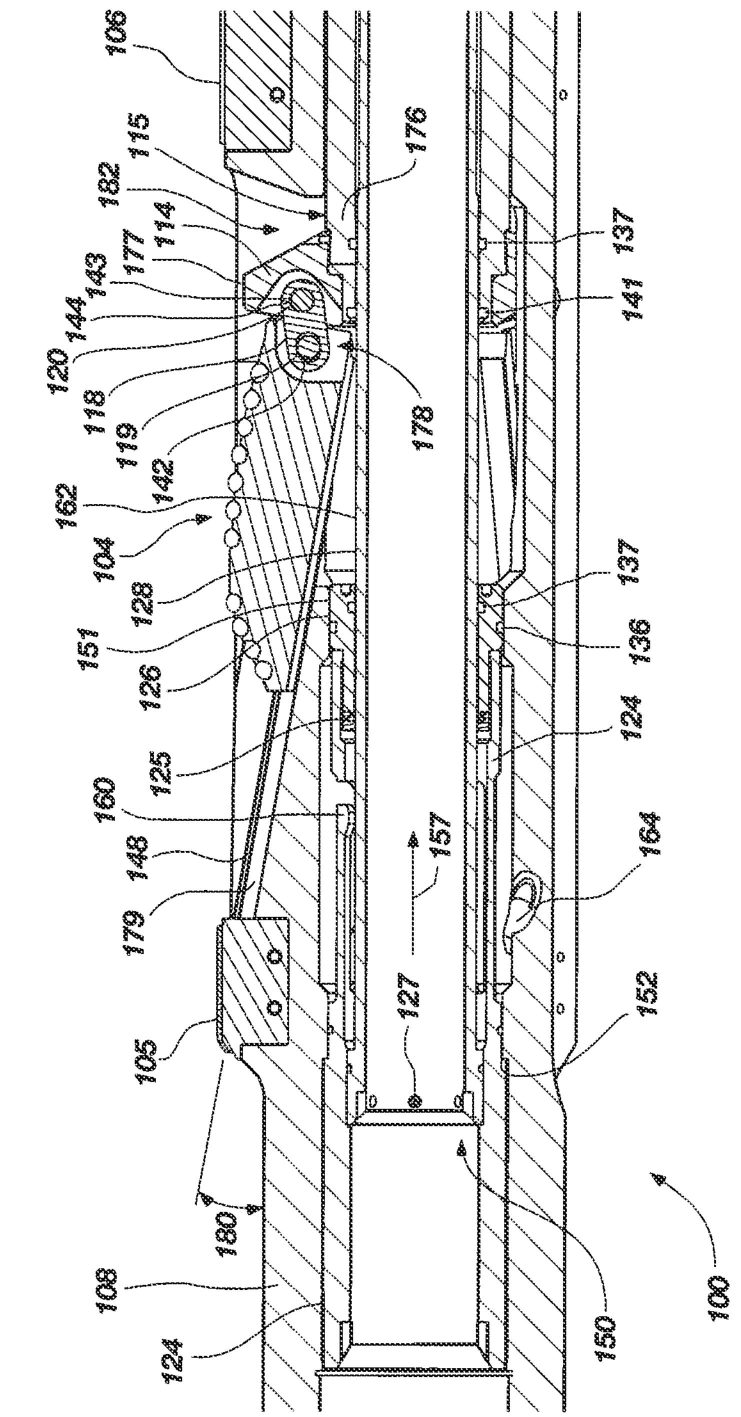

172
122
121
130
168
131
117
129
116
115
108
175
107
159
128
106
133
184
166
167
171
169
139
165
170
173
151
128
113
138
174
100

FIG. 5


106
115
176
182
114
177
143
144
120
118
119
142
178
137
141
162
104
128
151
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157
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136
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180
108
124
150
100

FIG. 6

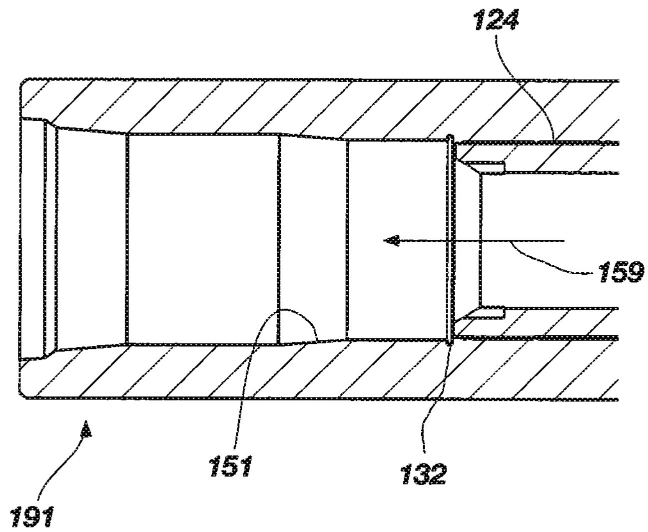

FIG. 7

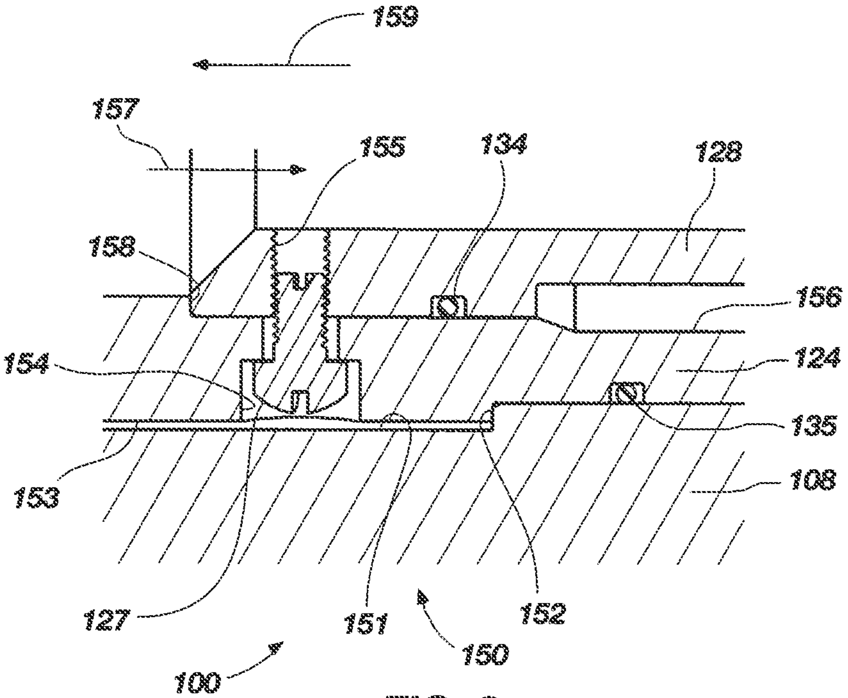
159
157
155
134
128
158
156
154
124
135
153
108
127
151
152
150
100

FIG. 8

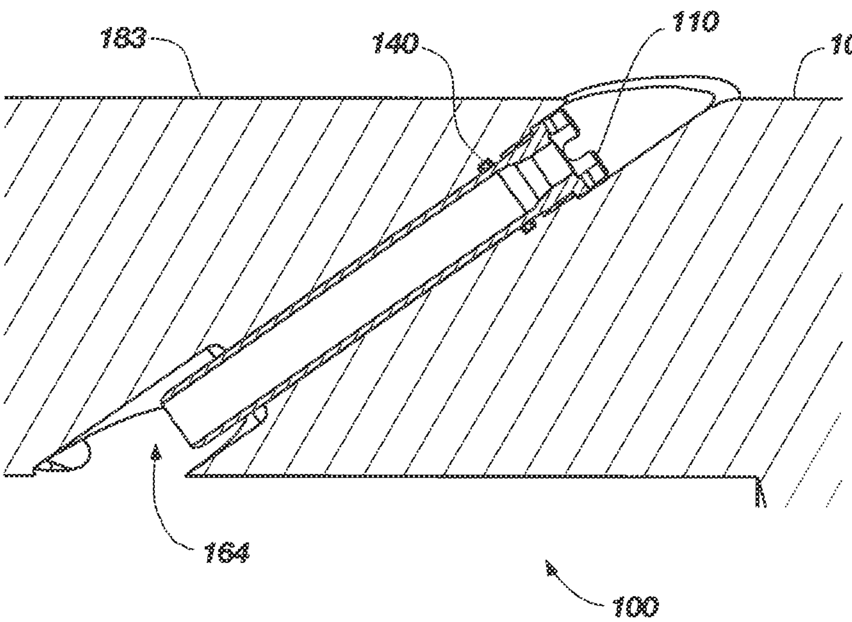
183
140
110
108
164
100

FIG. 9

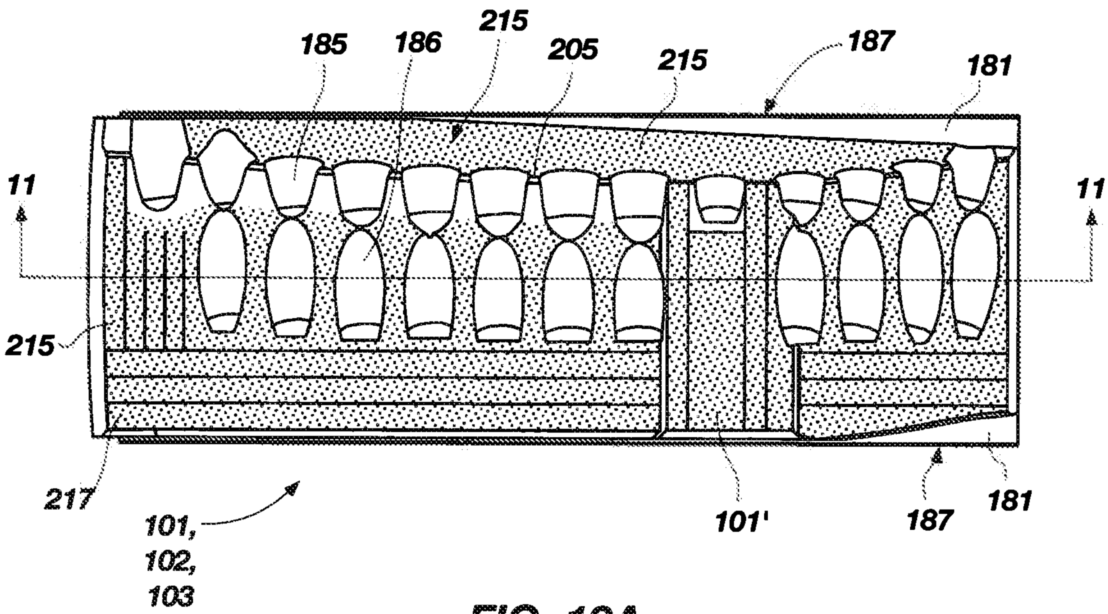

FIG. 10A

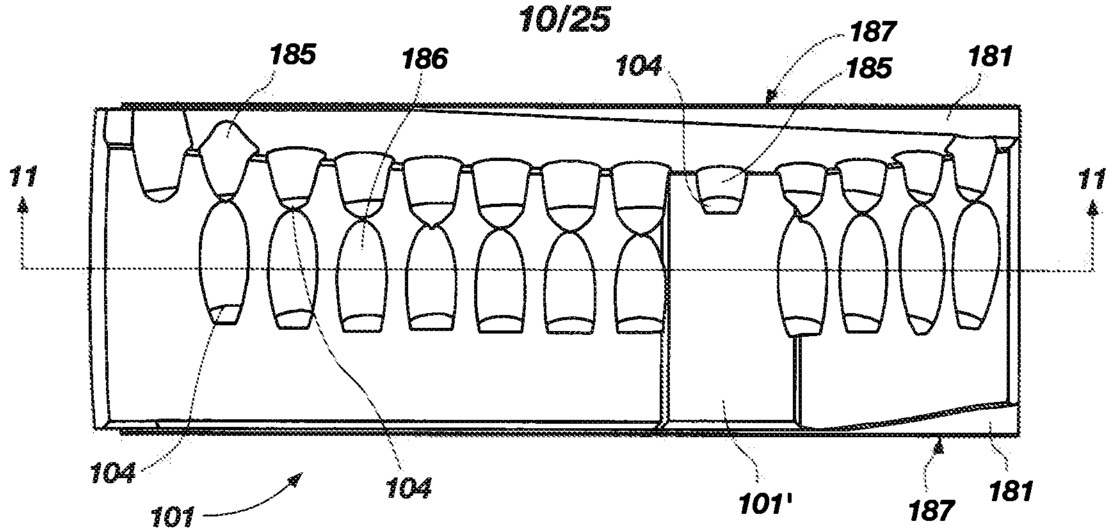

FIG. 10

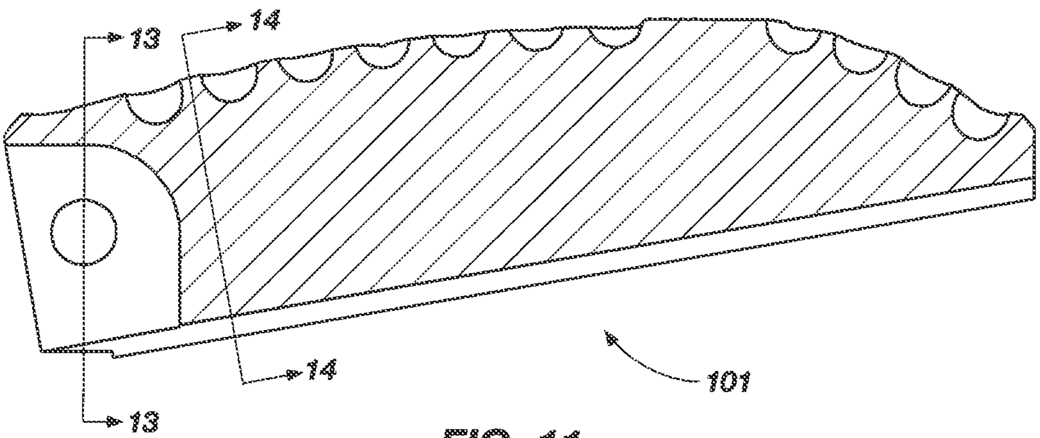

FIG. 11

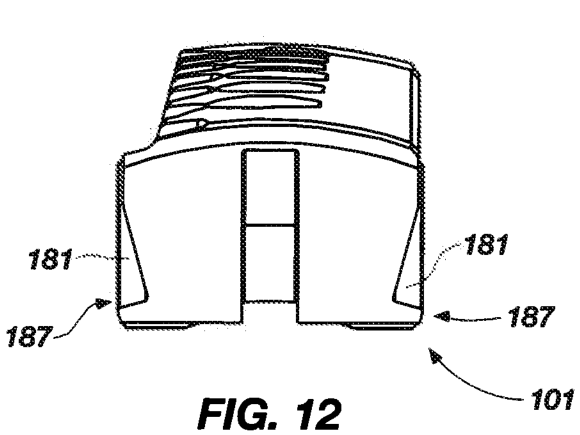

FIG. 12

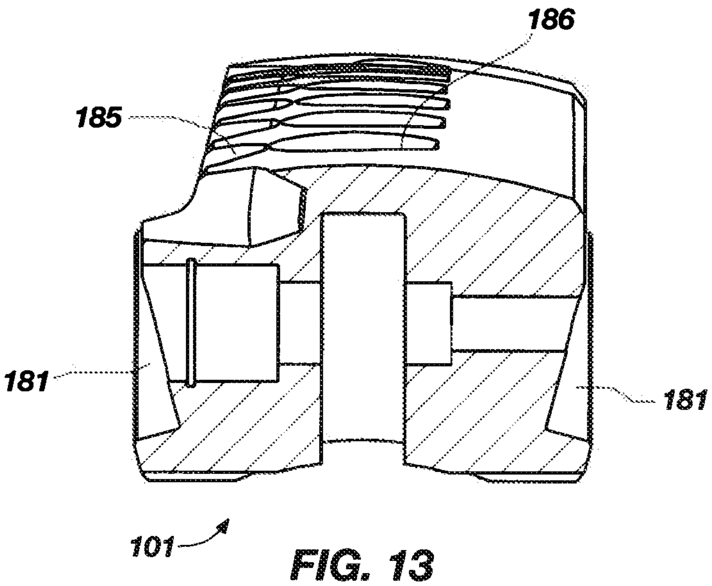

FIG. 13

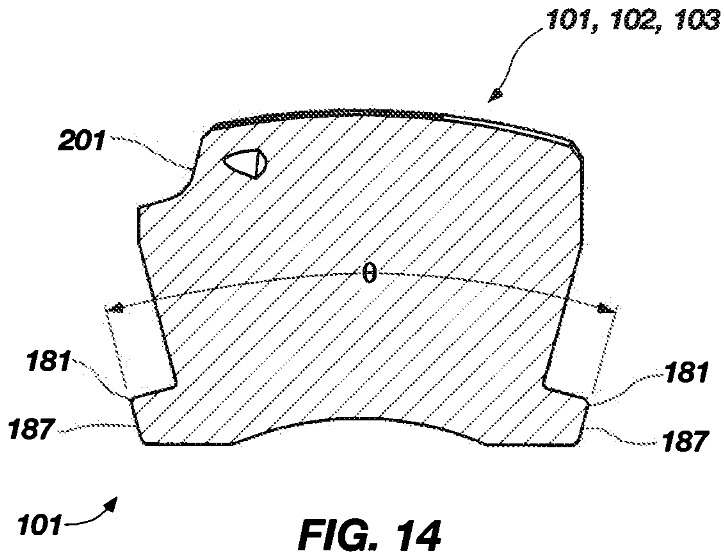

FIG. 14

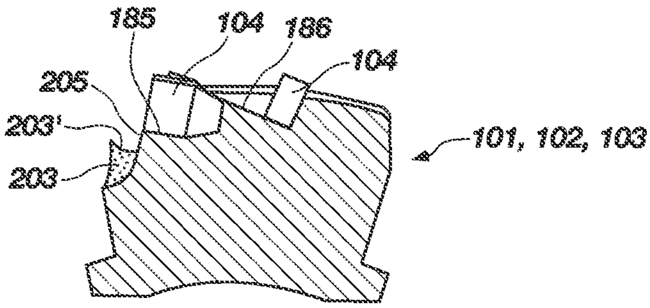

FIG. 14A

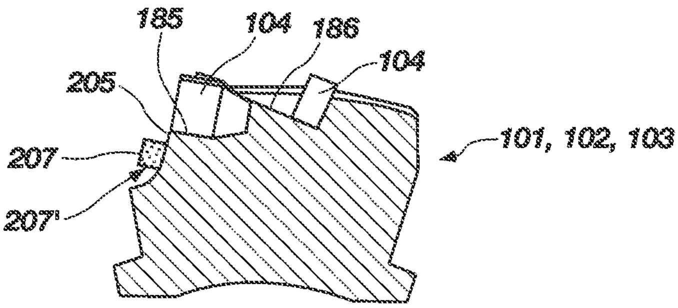

FIG. 14B

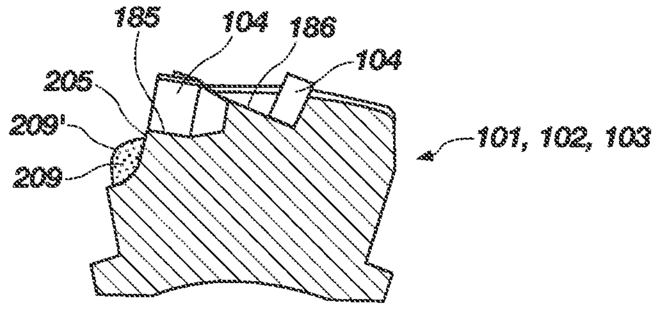

FIG. 14C

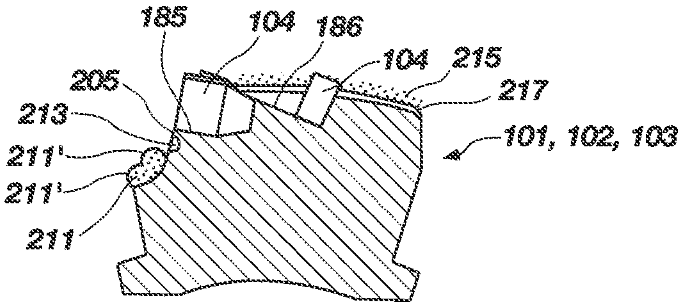

FIG. 14D

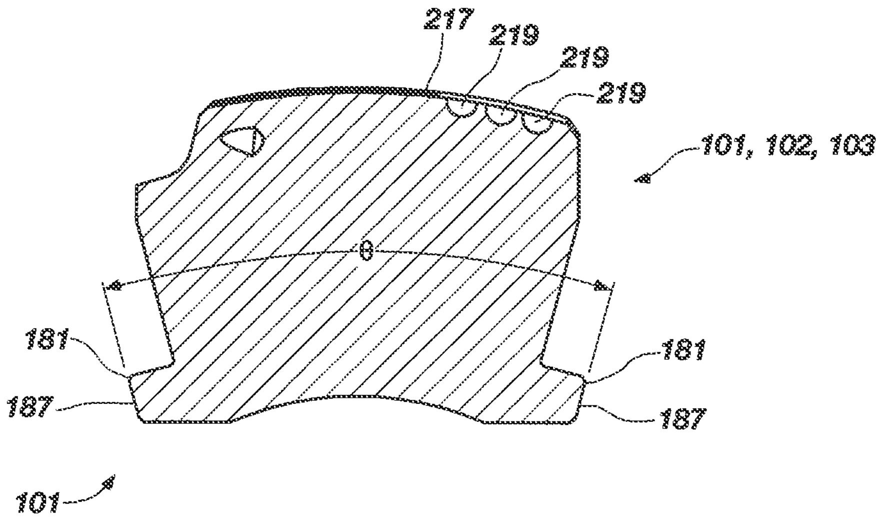

FIG. 14E

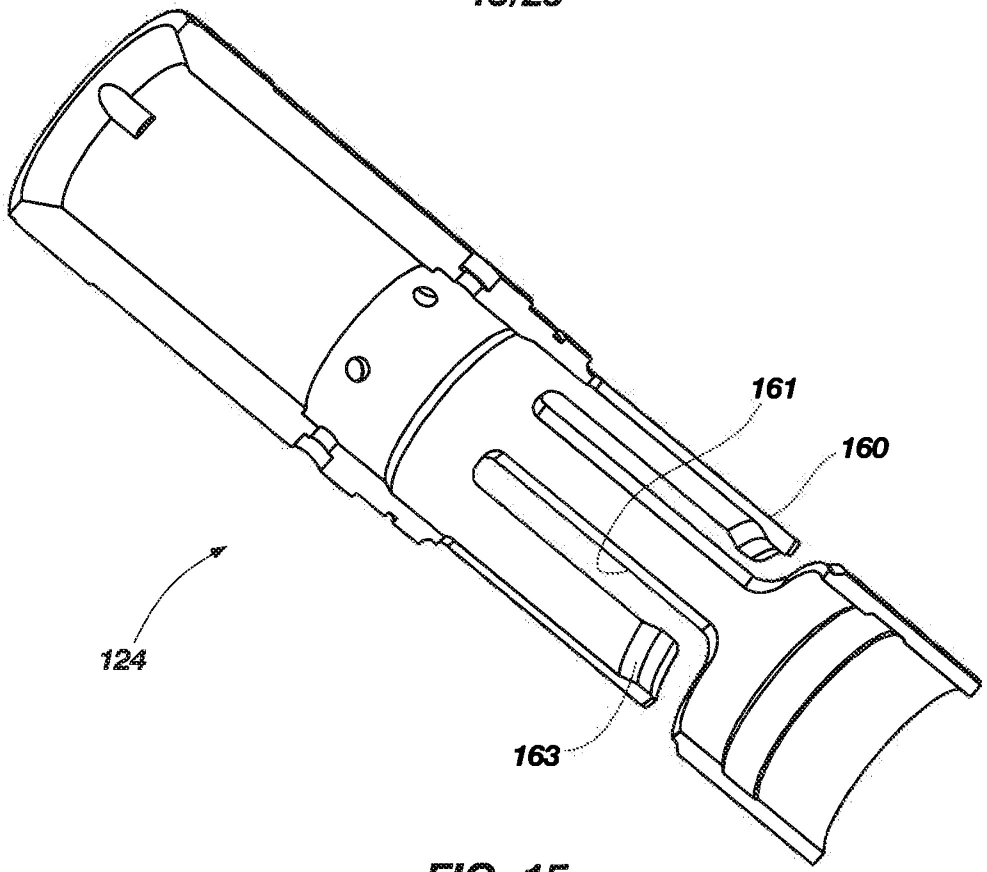

FIG. 15

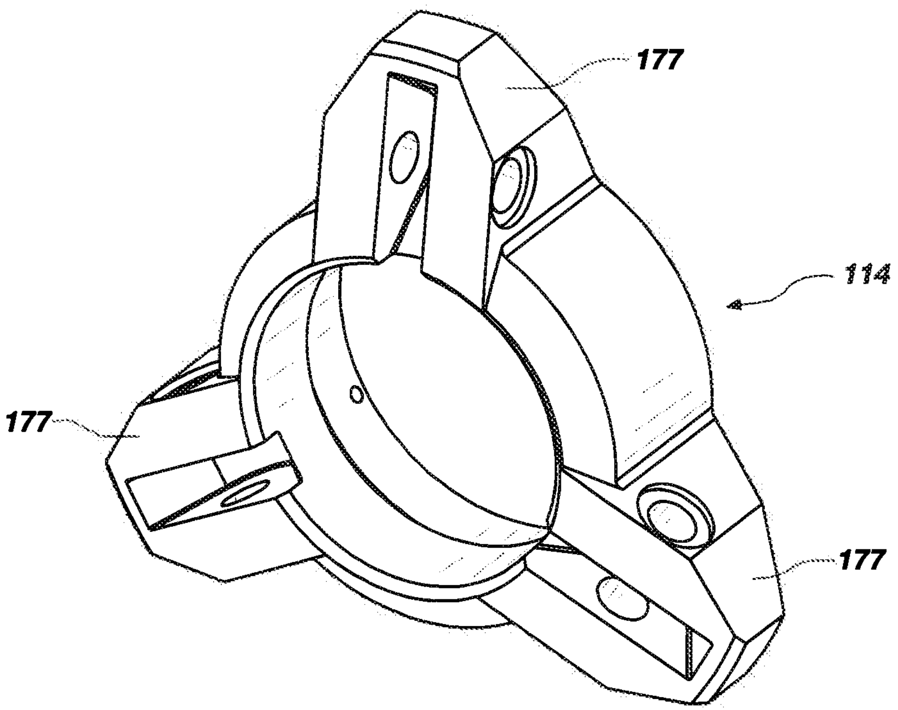

FIG. 16

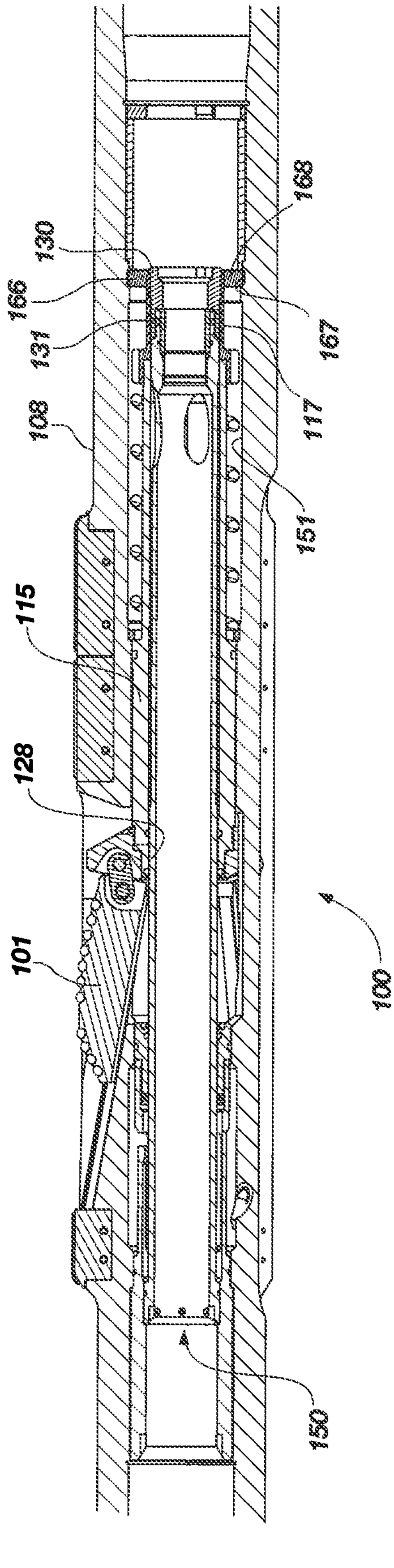

FIG. 17

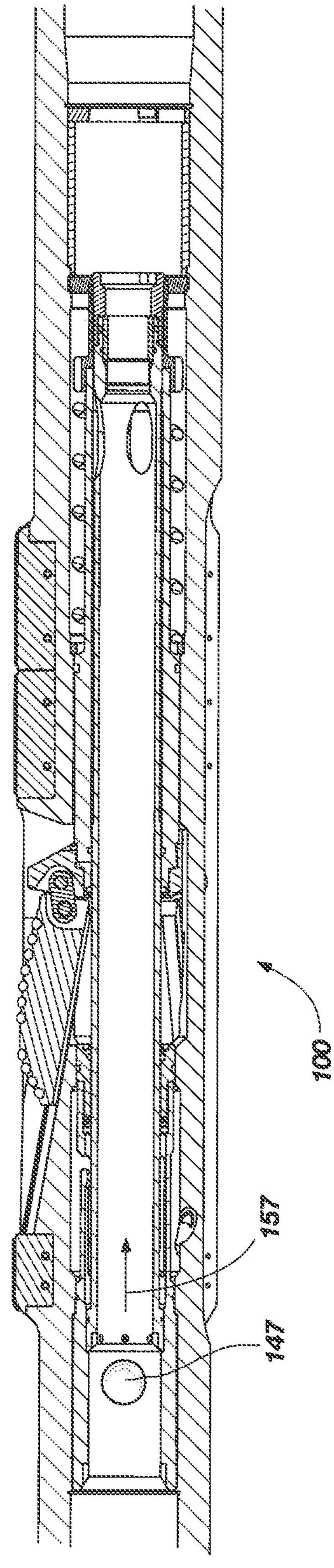

FIG. 18

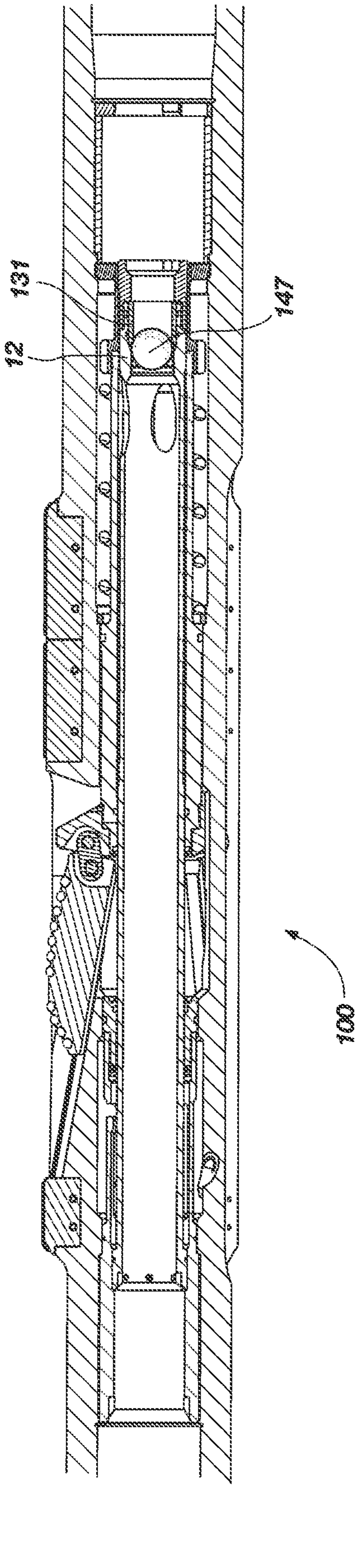

FIG. 19

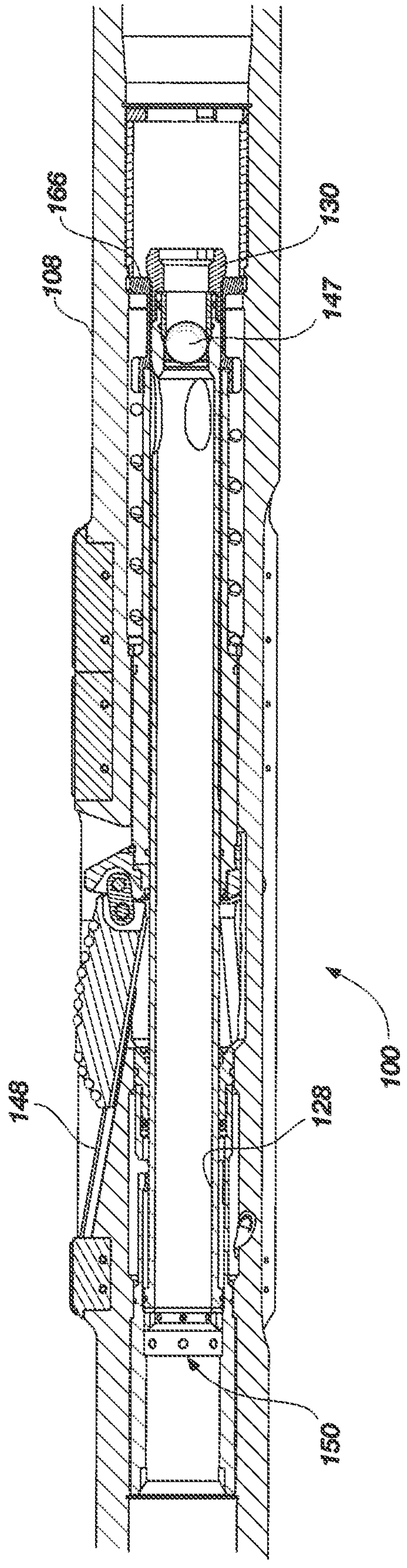

FIG. 20

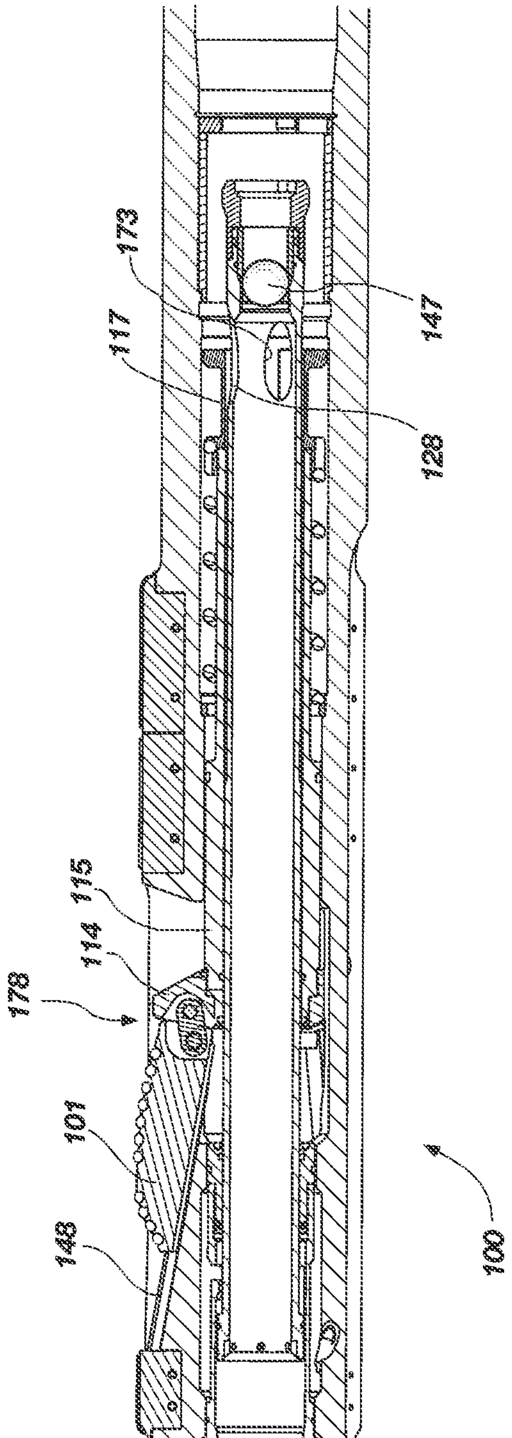

FIG. 21

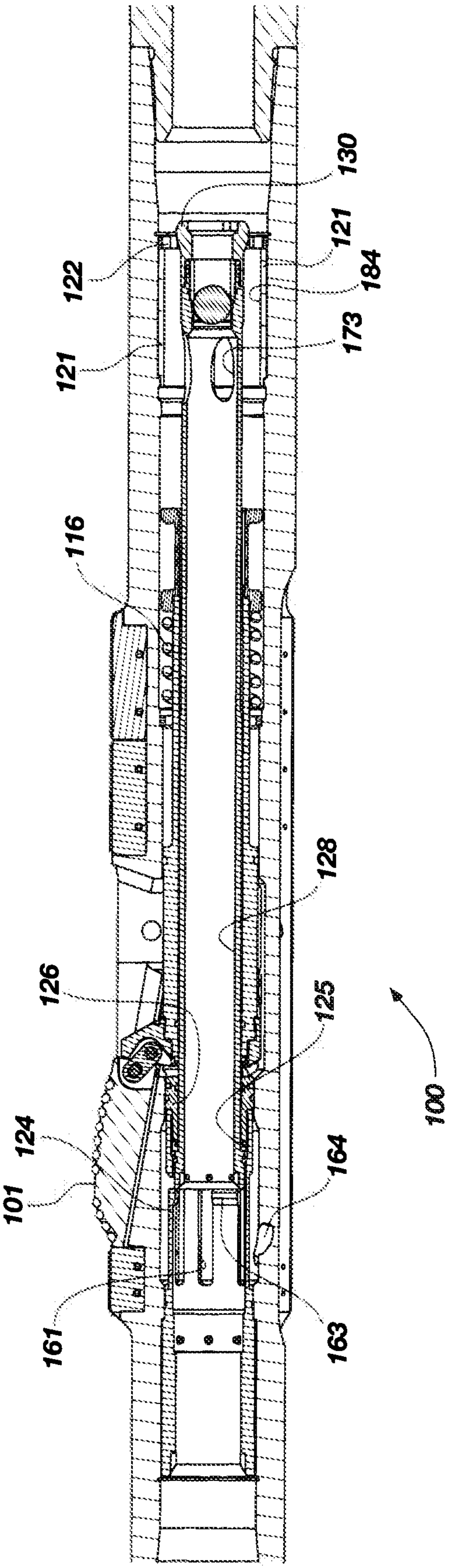

FIG. 22

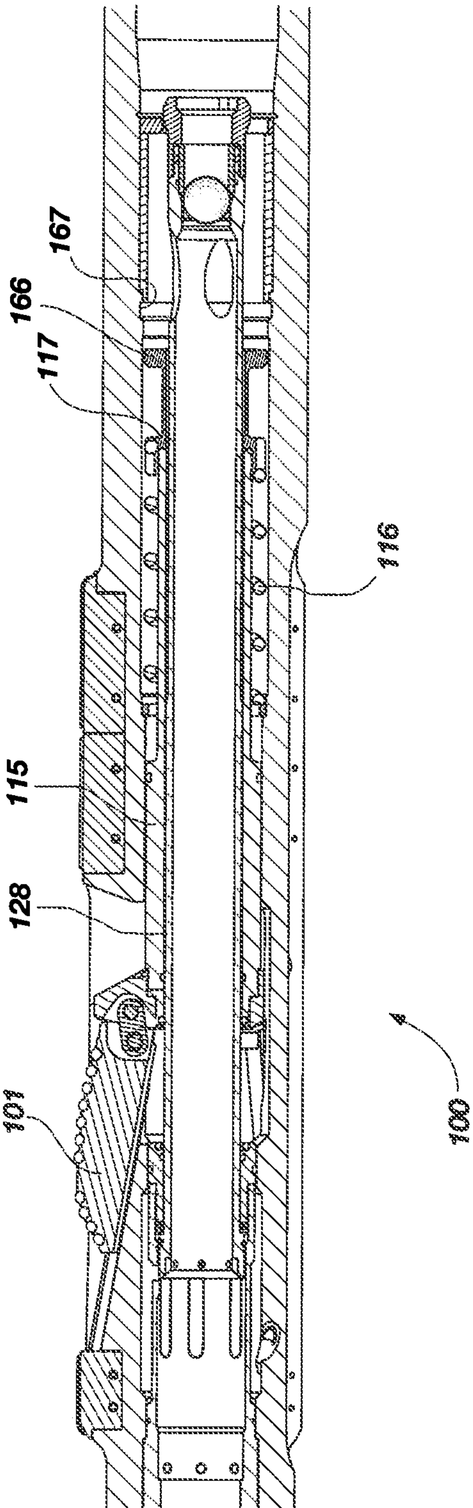

FIG. 23

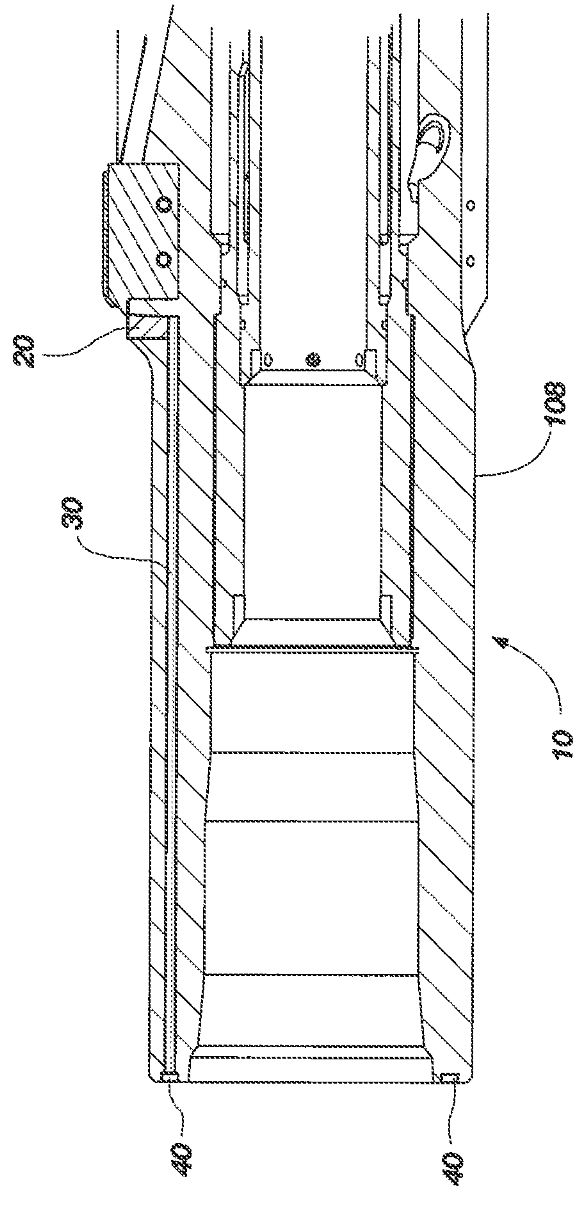

FIG. 24

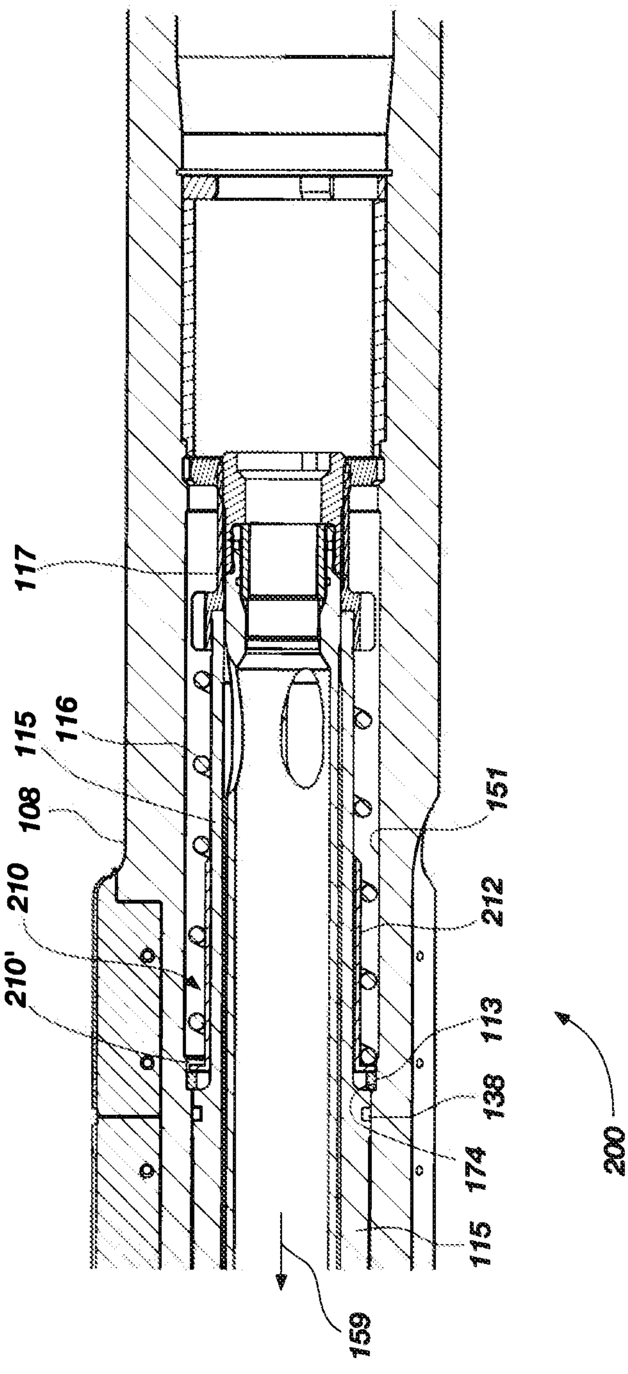

FIG. 25

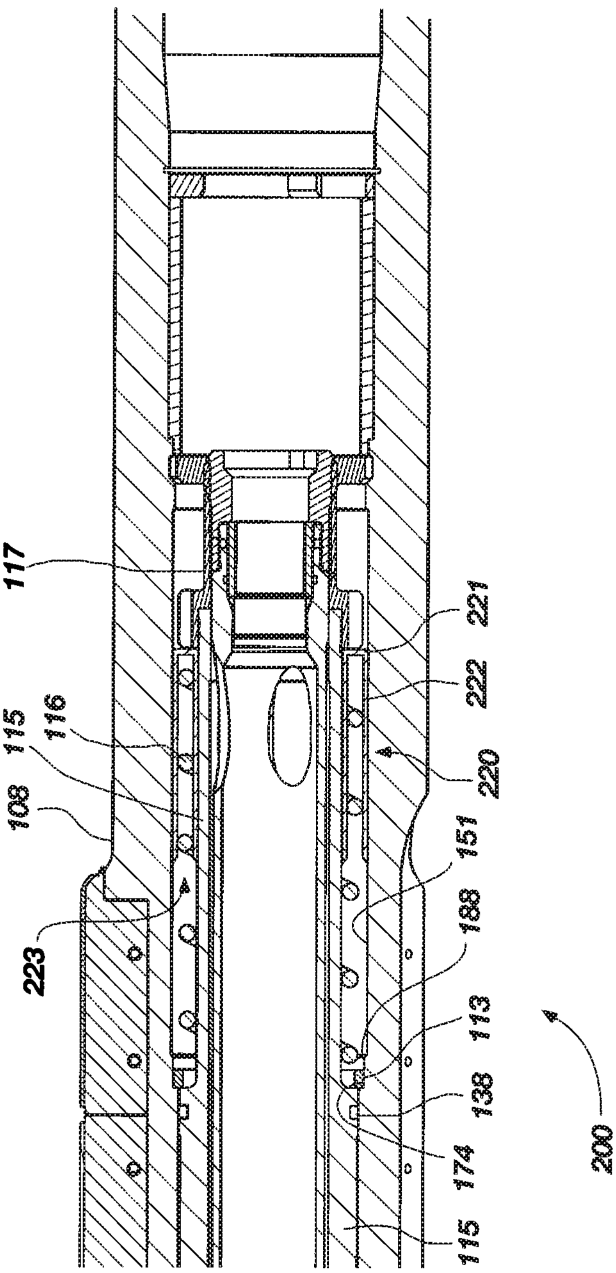

FIG. 26